UNIVERSITY OF ALBERTA

SIZE PERCEPTIONS UNDER SEVERAL FIELD CONDITIONS

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILLMENT TO THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF PSYCHOLOGY

EDMONTON, ALBERTA

AUGUST, 1968

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Size Perceptions Under Several Field Conditions" submitted by Carol Jeanette Ladan in partial fulfillment of the requirements for the degree of Master of Science.

ABSTRACT

The apparent increase of the size of the moon when seen on the horizon as compared to its size when seen at zenith has been a puzzle for centuries. Previous studies, usually revolving around one basic explanation, have generally been conducted in the natural setting.

In the present study, traditional explanations of the Moon Illusion were tested in the laboratory where an attempt was made to replicate the natural situation. The factors tested were: 1. eye elevation 2. apparent distance 3. texture gradients 4. objects in the scene or relative size and 5. brightness or photic gradient surrounding the moon. The first four factors have been postulated by earlier researchers as factors in producing the illusion. The fifth factor has never been explicitly studied. Effects due to combinations of these factors were studied, with an emphasis on testing additivity.

Results indicate that although terrain characteristic is an important factor in the production of <u>absolute</u> illusory size (see Glossary), it is not sufficient for explanation. Terrain is a complex variable, composed of both texture gradients and objects in the scene. Both factors produce absolute illusory size.

Eye elevation is also important in producing _absolute_ illusory size, as is the brightness or photic gradient surrounding the moon. However, when _relative_ illusory size (see Glossary) is considered, only representation of terrain produced illusory size. Further, the results of this study indicate that apparent distance and apparent size were not interdependent. On the basis of previous research by other authors, a suggestion was put forth concerning the method of measurement, i.e. simultaneous comparison (not employed in the present study) may produce different results than those provided by an indirect measure.

The conclusion drawn is that the traditional approach which posits a one-factor explanation is insufficient, since the Moon Illusion can be evoked by one of several conditions or combinations of conditions.

ACKNOWLEDGEMENTS

I am particularly grateful to Dr. T. M. Nelson not only for his interest and assistance in the preparation of this thesis, but also for providing both stimulation and incentive to a person who was, three years ago, at that particular age where one seeks a direction in life. Dr. Nelson's encouragement and guidance have always been highly appreciated.

Dr. F.N. Dyer and Dr. P. Swartz have my thanks for their participation on my committee and their critical appraisal of this thesis. Dr. N. Ginsburg deserves a special note of thanks for all the time and effort he expended towards the correction and completion of this thesis.

My thanks to David Allan for his assistance in the collection of data, and also to Jeanette Christians for her excellent typing.

And last, but not least, my husband Steve has my gratitude for his advice and assistance in the preparation of this thesis. His technical knowledge in the building of apparatus was invaluable. But most of all, I am indeed grateful for his limitless supply of patience.

Stephan

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INTRODUCTION

General Introduction To Problem

Origin of Problem:

Since antiquity, men have noticed and studied what has become known as the "Moon Illusion". This illusion refers to the increase of visual size of the moon when on the horizon as compared with its size at zenith. The illusory effects of the sun are even larger than those of the moon, but largely unstudied because of the intensity involved.

Knowledge of the moon illusion has prompted many experimental investigations. Some studies have involved observations of artificial targets (white disks and light spots) subtending the visual angle of the moon and thus have actually been laboratory studies of apparent size i.e. natural situations have not been simulated. Many others have used natural situations with consequent poor control and isolation of relevant variables.

Size - Distance Hypothesis:

The hypothesis which is still dominant was suggested by Ptolemy (2 A.D.): the apparent increase in the size of the moon on the horizon is due to its location beyond any terrestrial objects with which it is automatically compared, that is, moon size is a

function of the distance of the object. The difference between zenith and horizon sizes, he reasoned, occurred because filled space is nearly always perceived as greater than the same extent of unfilled space, and that, therefore, the horizon appears as farther away than the zenith and the size is relatively larger.

Ptolemy's hypothesis implies that the moon is seen against a sky which 0 does not see as equally distant at different elevations. This aspect of his hypothesis may be considered independently of objects, and, as such, is called the "Vault of Heavens Effect" by Minnaert (1954) who explicitly describes the shape of the sky over the earth consistent with Ptolemy. The "Vault" is not hemispherical but rather semiellipsodal in shape, having a ratio of "eye to horizon"/"eye to zenith" approximately equal to two. Independence of the shape of the sky from the presence of the moon is also supported by results from a study reported by Kaufman and Rock (1962) where, in ninety percent of the observations made by a group of ten Ss, the horizon sky appeared to be more distant even when the moon was not present. This result would be directly relevant to an explanation involving Emmert's Law of Afterimages. King and Gruber (1962) noted that the perceived size of

an afterimage projected on the sky varies in accordance with Emmert's Law when one considers the position of projection in relation to the sky as a flattened dome. Gruber and his collegues explained the Moon Illusion as a special case of Emmert's Law.

The mechanism by which apparent distance affects apparent size has not always been clear since both size and distance are responses and not stimuli based directly upon physical impingements (see either Bartley, 1958, or Gibson, 1966, for a discussion of this theoretical point.) Within this context of cue theory, the classic explanations of size perceptions were made in 1855 by Helmholtz (1964). Helmholtz' notion was that 0 makes an "immediate unconcious adjustment' of size for apparent distance.

An alternate hypothesis, but one which represents the same general approach, is the invariance hypothesis. Gibson (1966) suggests that the organization of information within the environment is sufficient to produce the effect. He contends that stimulus configurations may be considered to evoke what he called "misperceptions" (in preference to "illusions") independently of cognitive activity. Misperceptions

are considered to be the result of the straining of conditions or the result of "deficiencies in a process which usually comes out right, but for various reasons sometimes goes wrong".[1] In particular, in the case of the Moon Illusion, he would argue that the moon anywhere is undetermined by optical information[2] and is therefore phenomenally indefinite, but that the horizon moon is at least determined as very distant (the zenith moon being at an indefinite distance phenomenally) and hence as vaguely very large. The moon illusion is then nothing but the experience that the moon at the horizon (being at or behind the extreme of terrestrial distance) is suprisingly large.[3] That is, he does not presume that the discrimination depends upon explanation at a brain level, but that it is the stimulus configuration (such as a texture - gradient) on the retina which yields the impression of a plane receding, and therefore, the expected size. Supporting his position in part are results reported by Kaufman and Rock (1962). They found that terrain is important for full explanation of the illusion. However, their results are complex.

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[1] The Senses Considered as Perceptual Systems, p. 318

[2] by "optical information", Gibson refers to information provided by the content of the scene, NOT to output from ocular processes.

[3] communication, U. of A., Edmonton, 13/6/68

The importance of particular types of terrain was studied by Kaufman and Rock (1962). Some terrains were more effective than others, e.g. a street scene produced a size ratio ("size of horizon moon"/"size of zenith moon") of 1.66, while the effect for a scene without objects was approximately 1.37. It should be noted, however, that the effect of the buildings disappear, when, through the use of mirrors, the scene is inverted. The ratio in this situation is 1.28. This suggests that texture gradients per se are not sufficient (see also Boring's studies of 1940, 1941, 1942).

Angle - of - Regard Hypothesis:

Boring and collegues have presented the chief alternative to size - distance explanations. Boring and Holway (1940) and Boring (1941) turn instead to what they termed "angle - of - regard" and "elevation of gaze" hypothesis. Boring suggested that there is evidence that indicates that the phenomena depend upon the physiological properties of O and not upon external factors. In proof of this point, Boring noted that there is no size differences in photographs, although terrain is present. He and his colleagues point out that kinesthetic input from the ocular muscles varies with elevation of a target and present data indicates that

the illusion results from the cues provided by this input. The illusion is, according to this view, a special instance of "size constancy". The notion in general is that size constancy arises because the perceptual habits of 0 lead to correcting the size of the retinal image for the distance of the object. The apparent discrepancy between the results of Boring and Holway and Kaufman and Rock on this point may perhaps be related to the fact that the object judged was different in the two cases.

Other Hypotheses:

Other theories have arisen and enjoyed brief popularity. Explanations relating the illusion to the selective scattering of light of shorter wavelengths in the atmosphere (the reddish colour of the sun as it sets) have not gained much support (Kaufman and Rock, 1962, and Osaka, 1962).

Laboratory Studies:

Up to this point, the discussion has concerned measurements of the moon and sun in natural situations. The Moon Illusion has also been investigated in the laboratory where better control of variables is possible.

Schurr (1925) conducted a study in a zepelin hanger. Her method involved projection of disks of light upon the walls and ceiling of the hanger. Findings support the angle - of - regard theory, but Kaufman and Rock (1962) report being unable to replicate her experimental results. Also Gruber, King and Link (1961) produced the illusion in the laboratory only in cases where terrain was represented. While their results added support to Kaufman and Rock, it also appears that various experimental methods and situations influence results to an undetermined extent.

Methods of Denoting Response:

One important variable is the method used to determine the size observed. The illusion is often not found when the moon is compared simultaneously with a target (direct measurement) but is found when indirect measurement is used (see Minnaert, 1954, and Table I below). Minnaert concluded that memory plays a large role in the illusion.

Table 1

Experiment	Date	Direct	Indirect
Pozdena	1909	2.5	-
Schurr	1925	1.2 - 1.9	-
Boring and Holway	1940	.95 - 2.03 dependent on conditions of observation	-
Minnaert	1954	1.0	2.5 - 3.5 (both sun and moon illusions)
Gruber, King and Link	1962	-	1.5 - 1.6
Kaufman and Rock	1962	.99 - 1.34 dependent on presence of terrain	1.28 - 1.66 dependent on conditions of observation

Table 1: experimental results of previous studies for the perceived "Size of Horizon Moon"/"Size of Zenith Moon" by the methods of direct measurement (target viewed simultaneously with comparison stimulus) and indirect measurement (target viewed successively with comparison stimulus).

The Specific Problem:

Perception is the "immediate response of the organism to the energy impinging on sense organs." (Bartley, 1958).

Discrimination is the characteristic of perception which distinguishes it from pure physical and chemical interaction between the body and its surrounds. "To discriminate is to make a choice reaction in which contextual conditions play a deciding role" (Bartley, 1958).

A judgmental process does not consist of "a single unit of activity, or a single extended reaction, but rather a series of reactions, each of which can be taken as a unit, and called a perceptual response" (Bartley, 1958). O's terminal reaction or report is called a _judgment_.

It is conceivable that all prior investigators have isolated relevant variables but have assigned them too exclusive a role in explanation. Certainly most natural situations in which the illusion occurs contain more than one contributing factor (see Figure 1). The purpose of the present research is to discover the extent to which these factors contribute to the illusion alone or in combinations.

More specifically, the present investigation proposes to study size illusion by combining stimulus variables such as are found in the natural situation with precise laboratory control. The variables to be considered are those that have been thought important

Figure 1: An example of the Moon Illusion in a scene containing a combination of factors: Texture Gradients, a Photic Gradient surrounding the moon, and an object in the scene.
Eye elevation is fixed at the horizon position.

by prior investigators, namely, eye elevation; apparent distance; texture gradients and relative size. The role of the brightness gradient will also be evaluated, although it has never been explicitly studied. A judgmental process will be involved, since this is the process which takes place in the natural situation.

The present study will consider two different aspects of size: relative illusory size and absolute illusory size. The traditional comparison, i.e. "Size of Horizon Moon"/"Size of Zenith Moon" (variations of which were used by Boring [1939, 1943], and Kaufman and Rock [1962], etc.) will be termed relative illusory size. Deviation of size judgment from veridical "moon" size, i.e. thirty minutes, eight seconds of arc, will be termed absolute illusory size. Unless otherwise noted, results will be discussed in terms of the latter aspect of illusory size.

The following hypotheses will be tested:

1. a luminous circular target in the presence of any one of the aforementioned factors will produce an illusory size,

2. a luminous circular target in the presence of any combination of these factors will produce an illusory size,

3. a luminous circular target in the presence of any combination of these factors will show that the factors are not additive in their effects. Non-additivity would suggest that the hypotheses present true alternatives of explanation.

METHOD

Subjects:

Eight-one (81) summer school students drawn voluntarily from undergraduate courses in Psychology and Educational Psychology served as Ss. Data for seventy Ss was retained for analysis, ten Ss in each of the seven conditions. No specific age or economic group was employed and sex differences were not considered.

Of eighty-one Ss, eleven (11) were rejected. Rejection occurred if, in the initial condition (target but no brightness gradient), Ss judgments showed too great variability (see Appendix 1).

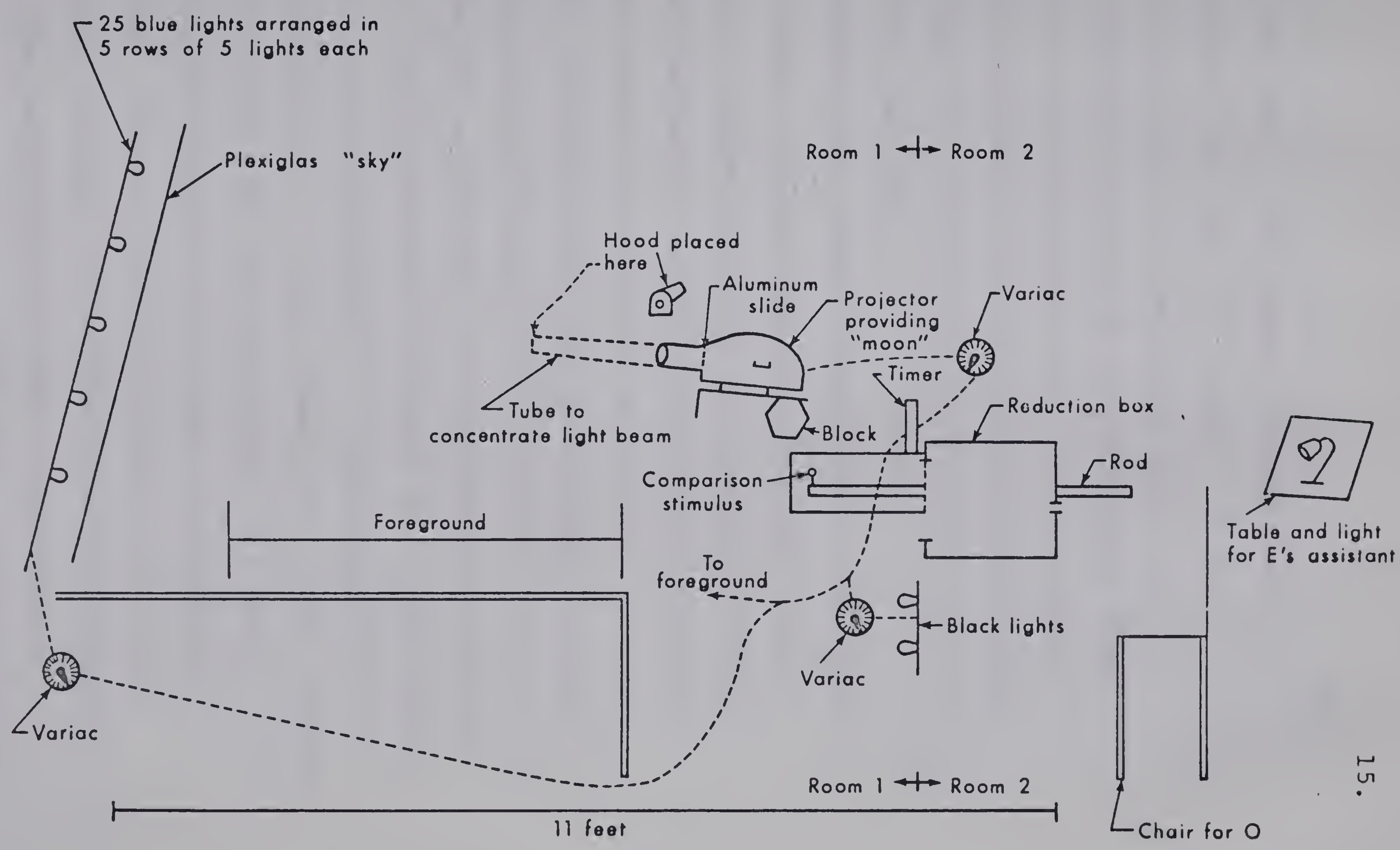
Because the individual differences in judging size are so marked, test trials determined which of the several available comparison stimuli was required (see Apparatus for description of comparison stimuli). The elevation two steps above the horizon was chosen for the test trial because its height was almost midpoint between the highest and lowest elevations. It might, therefore, be expected to produce an average judgment. When it happended that S's judgments were in a range beyond the existing one, he was invited to return at a latter date at which time a comparison stimulus of the correct size was made available.

Apparatus:

Research was conducted in two adjacent darkrooms prepared in the following way (see Figure II). In Room One, opposite the joining wall, two sheets of Plexiglas were illuminated from behind and tilted so the top and bottom were equally distant from S. This served as the "sky". The stimulus target was projected on this surface by a Leitz "Prado 500" projector which was fitted with an aluminum slide containing a circular hole of the correct diameter to provide a "moon" on the Plexiglas sky which would subtend a visual angle identical with that subtended by the vertical moon in the natural situation. The projector was also fitted with a blocking lens to concentrate the light beam and a tube to prevent scattering of light. A small hood containing a circular hole placed over the end of the tube provided the initial condition. The diameter of the hole was of such a size that it would allow only the projected light for the "moon" to pass, thus eliminating the photic gradient from the initial condition. Removal of this hood provided the condition of target with surrounding gradient of brightness.

The stimulus target was equivalent in all possible respects (e.g. visual angle, brightness in cdls./in.^{2})

Figure II Schematic Drawing of Apparatus (see text)



to the real moon. The diameter of the "moon" on the Plexiglas "sky" was 1.19 inches. At S's position slightly over eleven feet away, this target subtended an angle of thirty minutes, eight seconds, or that subtended by the veridical moon. A Variac attached to the projector provided a means of equating the brightness of the stimulus target to that of the real moon.

Elevation was varied through use of a six-sided block similar to those supporting drafting tables. Six equally spaced elevations were employed, varying from zero degrees to twelve degrees thirteen minutes, i.e. the highest elevation was at an angle of twelve degrees, thirteen minutes from S's sensible horizon.

Beneath the Plexiglas "sky", a black table supported the seven types of interchangeable stimulus fields. The fields were as follows: 1. a city skyline scene 2. a rotating windmill 3. a texture gradient 4. line perspective 5. a city scene plus texture gradient 6. a city scene plus line perspective 7. a scene with only the background and target (unstructured condition). The city skyline consisted of a row of four model buildings interspersed with small plastic cars. The texture gradient and line perspective consisted of luminous design on a flat white background

and tilted approximately forty degrees from horizontal. All fields were supported by small black benches invisible to S. In the condition where a combination of fields occurred, the line perspective or texture gradient was placed directly in front of and below the city skyline (see Figures III to IX).

Building windows and sky were radiant, but the field was luminous. Luminous substances were activated by four black lights whose output was controlled by a Variac. A timer provided control of inspection time.

The wall separating the two experimental rooms housed a reduction screen which permitted binocular vision of the experimental situation. This screen was built into a box, a portion of which was illuminated from behind and contained a movable rod with a cardboard circle attached in an upright position at the end most distant from S. The cardboard circle was the comparison stimulus. It was viewed binocularly by S. As mentioned before (see Subjects), the comparison stimulus was interchangeable. The diameters of the comparison disks were .14 in., .25 in., .38 in., .50 in., and thereafter increased at .10 in. intervals, the largest disk being 1.50 in. in diameter.

Figure 3: Unstructured Condition with No Photic Gradient.
The Unstructured Condition consisted of the moon and background only i.e. objects and terrain were not represented in this condition. The "moon" is shown at an elevation of 7°21' from S's sensible horizon with the horizon at lower edge of the photograph. (approx.)

Figure 4: City Scene (with Photic Gradient)
The City Scene consisted of four model buildings illuminated from the interior, and a number of small plastic cars, all mounted on a bench painted flat black. Shadows seen are reflections in the Plexiglas "sky" which are noticeable from the angle of the photographer, but not noticeable from the slightly different angle of the S.
The "moon" is shown at an angle of 7°21' from S's sensible horizon.

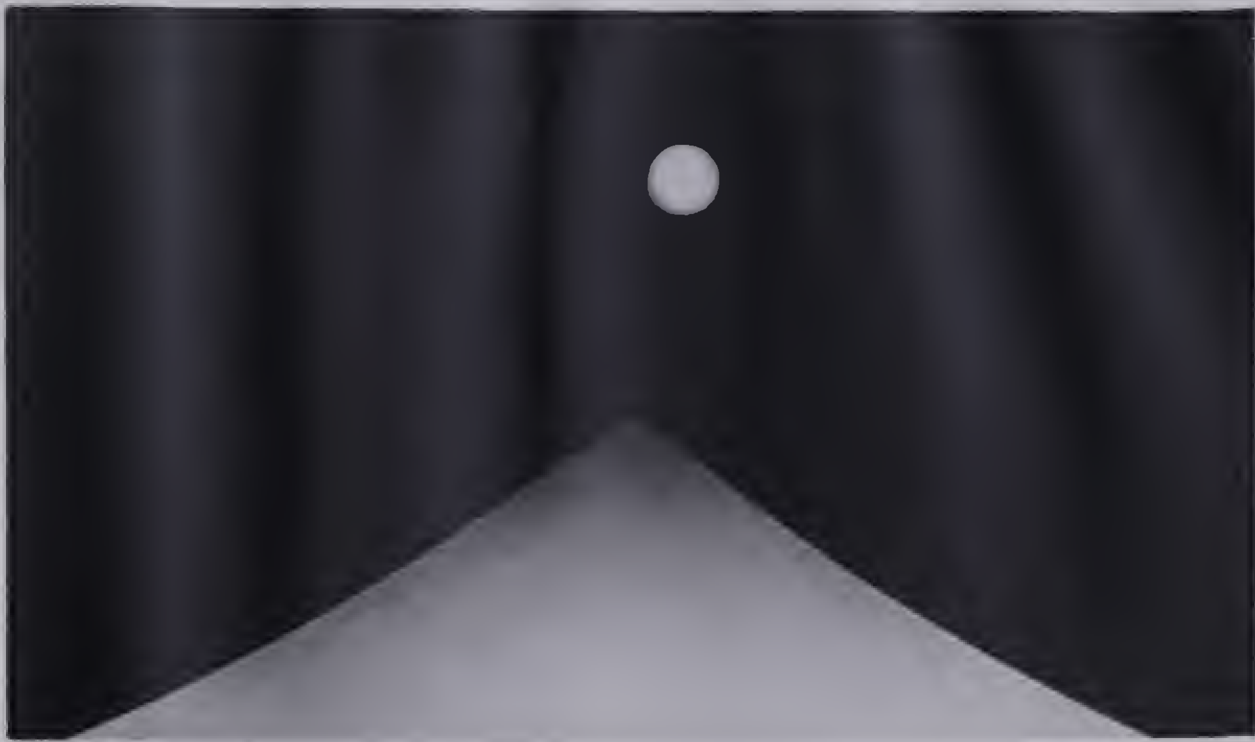


Figure 5: Line Perspective (No Photic Gradient)
The "figure" portion of the Line Perspective consisted of a design in luminous paint activated by four black lights.
The surrounding "ground" was painted with flat white paint, which when illuminated by the four black lights, merged into the background.
The "moon" is shown at an angle of 2°27' from <u>S</u>'s sensible horizon.

Figure 6: Combination of City Scene plus Line Perspective (with No Photic Gradient)
In the Combination scene, the Line Perspective scene was supported directly in front of and below the city skyline scene.
The "moon" is shown at an angle of 4°54' from <u>S</u>'s sensible horizon.

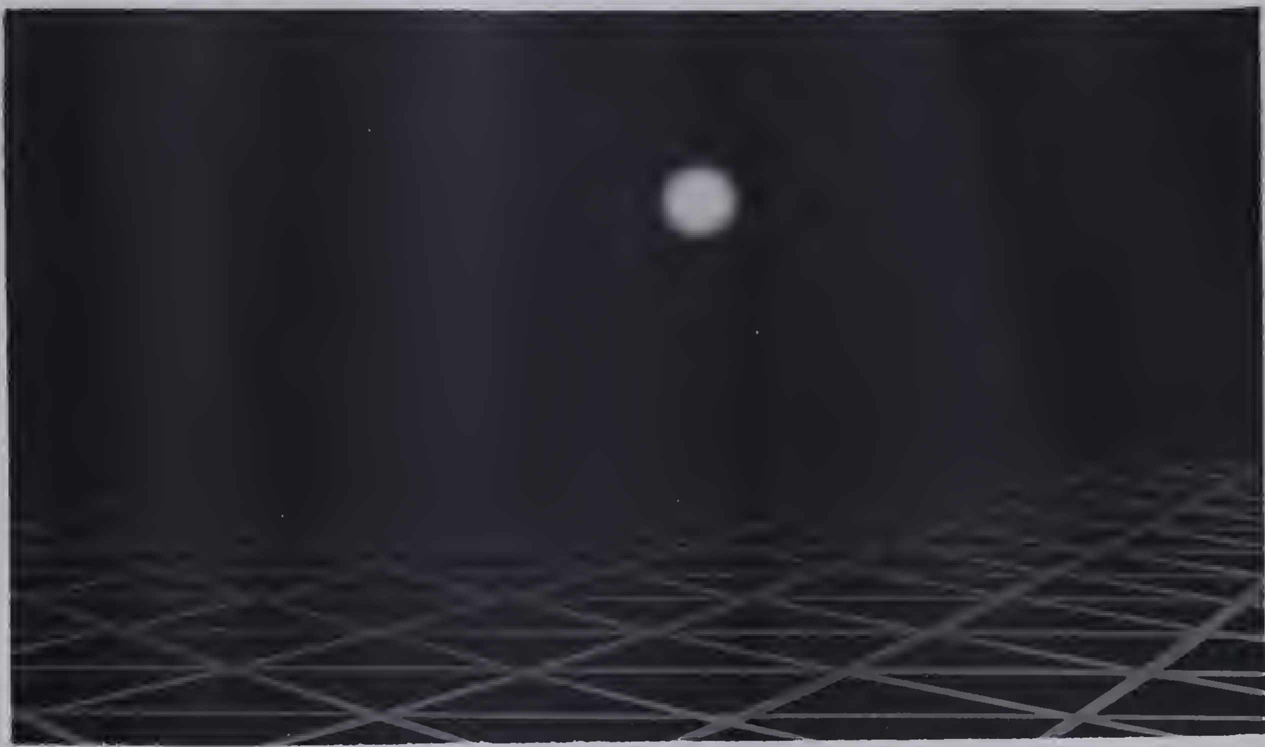


Figure 7: Texture Gradient (with No Photic Gradient)
The "figure" portion of the Texture Gradient consisted of a design in luminous paint activated by four black lights.
The surrounding "ground" was painted with flat white paint, which when illuminated by the four black lights, merged into the background.
The "moon" is shown at an angle of 2°27' from S's sensible horizon.

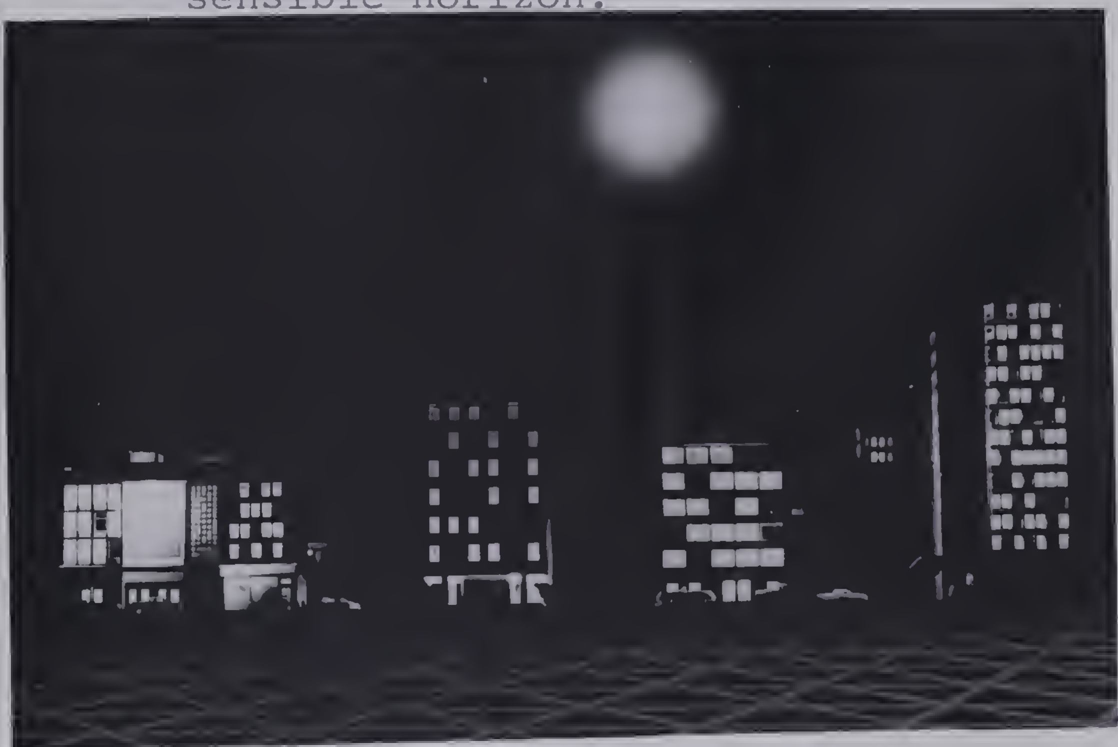


Figure 8: Combination of City Scene plus Texture Gradient (with Photic Gradient Condition)
In the Combination scene, the Texture Gradient scene was supported directly in front of and below the city skyline scene. The "moon" is shown at an elevation of 7°21' from S's sensible horizon.

Figure 9: The Windmill scene - no "moon" is present in the Plexiglas "sky". The windows of the Windmill radiated a small amount of light. During experimentation, the blades of the Windmill were in motion, and at the horizon level, the blades momentarily obscurred the moon as they rotated.

The movable rod was calibrated in visual angle. The scale was not visible to S (see Appendix 2).

Also in the second room was a table and small shaded light to aid E's assistant in recording data.

Above S's head, but within reach from his sitting position, a cable ran between two pulleys, one attached to the far wall of the second experimental room, the other, attached to the wall to the side of and behind the Plexiglas "sky". Attached to this cable was a target of red yarn. The wall blocked S's view of the cable and target once it had left Room Two. A tape measure was strung beside the cable in the first experimental room, but did not extend into Room Two.

Procedure:

Ss were run individually at times of their convenience. When S arrived, he was shown into the second experimental room and seated in front of the reduction screen. This was to be his position throughout the experiment. E conversed briefly with S to put him at ease in the experimental situation. E then began the instructions. S was instructed that by glancing back and forth from the stimulus target to

the comparison target, he was to adjust the movable rod until the size of the circle matched the size of the "moon". S was also informed that a bell would warn of an imminent presentation. Lastly, S learned that in the first part of the experiment he would judge only the target, and in the second part he would judge the target surrounded by a gradient of brightness.

Test trials were given in order to acquaint S with the stimulus and also to determine which comparison stimulus would be needed. The number of test trials was dependent upon S's satisfaction with the size of the target as compared to the size of the stimulus. Four trials was the maximum needed. As an added precaution, S was assured that a change of comparison target would be possible during the first few trials if there was any doubt of the sufficiency of range. E then answered any questions of procedure, and the room was darkened and the session began. E retired to Room One, rang the warning bell and switched on the apparatus. S made a judgment of the initial condition during the twenty-second time interval allowed. In all cases, the interval was sufficiently long for S to make the judgment. E's assistant recorded the data and adjusted the rod to either its unextended or most extended position, depending

on whether the next trial was ascending or descending (randomly determined). E adjusted the block under the projector, rang the bell and the next presentation began. Thirty presentations were given i.e. five trials at each of the six elevations. Order of presentation was randomly determined.

S was informed that the second part of the experiment would now begin. S was instructed to judge the target surrounded by the gradient of brightness and cautioned not to include the gradient in his judgments. E returned to Room One, removed the hood in order to produce the 'photic gradient' condition (see Apparatus) and the session proceeded in the same manner as that of the initial condition.

The six elevations were presented randomly, but S saw the same stimulus field throughout. Which field was seen was randomly determined. It was not possible to randomize the fields for each S because of the time required to set up each condition.

At the conclusion of the session, E returned to the room in which S sat and took four measures of apparent distance. Two methods were used: 1. depth estimation, 2. magnitude estimation. Two measures (made from memory) were taken by each. S was first instructed to adjust the cord (see Apparatus for

description) so the position of the target would be as distant as the position of the horizon moon (depth estimation). The judgment was made, and the data recorded. S was asked to repeat the measure, considering the moon of highest elevation instead of the horizon moon. S was not allowed to observe the stimulus during measurement, since the match was to be made employing memory. A small number of Ss were unable to make this judgment, for reasons that can only be speculated. In such a case, S was asked to give a judgment in feet and inches. The same two distances were then measured by the method of magnitude estimation. The question given was as follows: "If the eyepiece is (e.g. 37) units in length, how many units is the horizon moon from the eyepiece?" The eyepiece was always used for comparison purposes and as the zero point.

The distance measures concluded the experiment. S was shown the equipment in the first experimental room and the purpose of the study was explained.

RESULTS

An initial comparison of size judgments as differing from veridical size of the target was made by means of a χ^2 on the major factors, excluding the apparent distance variable since it is here a correlate of size rather than a determinant. Results showed high reliability ($\chi^2 = 700.30$; df = 3; $p \ll .001$).

An analysis of variance for size data was run by APL using a program written particularly for the problem since no such program is found in the public libraries (see Appendix 3). A subsequent check was done by hand.

The results of the analysis of variance are shown in Table II. Those effects starred (*) are significant at the .05 level.

The A effect (foregrounds or scenes) was not significant at the .05 level ($F = .915$; df = 6,63; $p > .25$). However, Duncan's New Multiple Range Test (to compare each scene with every other) showed that several comparisons produced significant results. The results of Duncan's test are given in Table III. Nine of the twenty-one comparisons show significance at the .05 level. These are marked in the table and will be discussed later.

Table II

Source	Sum of Squares	df	Mean Square	F	p
A (scenes)	167829.5	6	27971.58	.915	>.25
S(A)	1926434.5	63	30578.33	-	-
B (photic vs. no photic)	3932.1	1	3932.10	1.910	>.10
A X B	6358.3	6	1059.71	.515	>.25
S(A) X B	129715.8	63	2058.98	-	-
C (elevations)	102986.3	5	20597.27	47.379	<<.005*
A X C	35576.1	30	1185.87	2.728	<.005*
S(A) X C	136940.2	315	434.73	-	-
B X C	654.4	5	130.88	.520	>.25
A X B X C	11146.6	30	371.55	1.475	≃.06**
S(A) X B X C	79349.2	315	251.90	-	-

* Significant
** Approaching Significance

Table 2: Analysis of Variance of size effects for A (scenes or foregrounds), B (photic gradient vs. no photic gradient), and C (angle of elevation). Sums of squares, degrees of freedom, mean squares, F's and probabilities are shown for main effects, second-order interactions and third-order interactions.

Table III

	T.Gr.	L.P.	C.S.	Wind-mill	U.C.	C.S., T.Gr.	C.S., L.P.
T.Gr.	X	N.S.	N.S.	N.S.	S.	N.S.	N.S.
L.P.	X	X	S.	S.	S.	S.	N.S.
C.S.	X	X	X	N.S.	N.S.	N.S.	S.
Wind-mill	X	X	X	X	N.S.	N.S.	S.
U.C.	X	X	X	X	X	N.S.	S.
C.S., T.Gr.	X	X	X	X	X	X	S.
C.S., L.P.	X	X	X	X	X	X	X

Table III: results of Duncan's Multiple Range Test (to compare each scene with every other). N.S. indicates comparisons in which there were no significant differences. S. indicates comparisons in which significant differences occurred. Protection level of Duncan's in this situation is 73.5%.

U.S. refers to Unstructured Condition.

In order to determine the effect of the presence of scene vs. absence of scene, t-tests compared each scene with the Unstructured Condition. Table IV presents results of this comparison for total data (both presence and absence of photic gradient), whereas Table V presents results of the data from the photic gradient condition only. Table IV shows that the Combinations (C.S. plus L.P.) differs significantly from the Unstructured Condition, with differences between Line Perspective and Unstructured Condition approaching significance ($p \approx .06$). The t-tests comparing each scene with the Unstructured Condition under the photic gradient condition only (Table V) produced the same results found significant in Table IV, although the effect was reduced somewhat. An added result is that the differences in effect between Unstructured Condition and Texture Gradient approaches significance ($p \approx .06$). Results for these three comparisons agree with results produced by Duncan's Test (see Table III).

The effect of scenes on relative illusory size was investigated by computation the ratio, "Size of Horizon Moon"/"Size of Zenith Moon". These results are presented in Table VI. This size index is greatest in the Combination conditions, relatively large in the City Scene and Texture Gradient conditions,

Table IV

Foreground	X	t	df	p
City Scene	1233.2	.648	18	>.25
Line Perspective	1510.4	1.709	18	>.05 (≈.06)
Texture Gradient	1393.2	.538	18	>.25
Windmill	1166.0	.407	18	>.30
City Scene plus Line Perspective	1574.1	2.169	18	<.05 *
City Scene plus Texture Gradient	1218.0	.670	18	>.25
Unstructured Condition	1108.1	-	-	-

Table IV: t-tests comparing each scene with the Unstructured Condition over both photic gradient and no photic gradient condition. df is the result of $n_1 = n_2 =$ 10 Ss.

* indicates significance at the .05 level.

Table V

Foreground	X	t	df	p
City Scene	604.6	.367	18	>.35
Line Perspective	770.3	1.366	18	>.05 (≈.09)
Texture Gradient	702.2	1.621	18	>.05 (≈.06)
Windmill	578.8	.152	18	>.40
City Scene plus Line Perspective	825.6	1.902	18	<.05 *
City Scene plus Texture Gradient	645.0	.369	18	>.35
Unstructured Condition	567.8	-	-	-

Table V: t-tests comparing each scene with the Unstructured Condition over photic gradient condition only. df is the result of $n_1 = n_2 = 10$ Ss.

* indicates significance at the .05 level.

Table VI

Foreground	No Photic Gradient	Photic Gradient	Overall
City Scene	1.45	1.35	1.40
Line Perspective	1.29	1.09	1.19
Texture Gradient	1.32	1.41	1.36
Unstructured Condition	1.06	1.04	1.05
Windmill	1.18	1.13	1.16
City Scene plus Line Perspective	1.78	1.41	1.60
City Scene plus Texture Gradient	1.36	1.59	1.48
Overall	1.35	1.29	1.32
Overall without Unstructured Condition	1.40	1.33	1.36

Table VI: Ratio of "Size of Horizon Moon"/"Size of Zenith Moon" for each of the foregrounds or fields and for each of 'no photic gradient' and 'photic gradient' conditions. Overall ratios have been calculated across 'photic gradient' - 'no photic gradient' for each field and also across fields for each of the 'no photic gradient' and 'photic gradient' conditions. In addition, this latter ratio has been calculated across fields, excluding the Unstructured Condition. "Zenith" represents the highest angle of elevation, namely 12 degrees, 13 min. from S's sensible horizon.

with approximately twenty percent increase in the Line Perspective and Windmill conditions. The Unstructured Condition produced only a small increase.

The analysis of variance (Table II) also shows the B main effect (photic gradient vs. no photic gradient) to be not significant ($F = 1.910$; $df = 1,63$, $p > .10$). A t-test, as an alternate, confirmed this ($t = 1.24$; $df = 1$; $p > .20$).

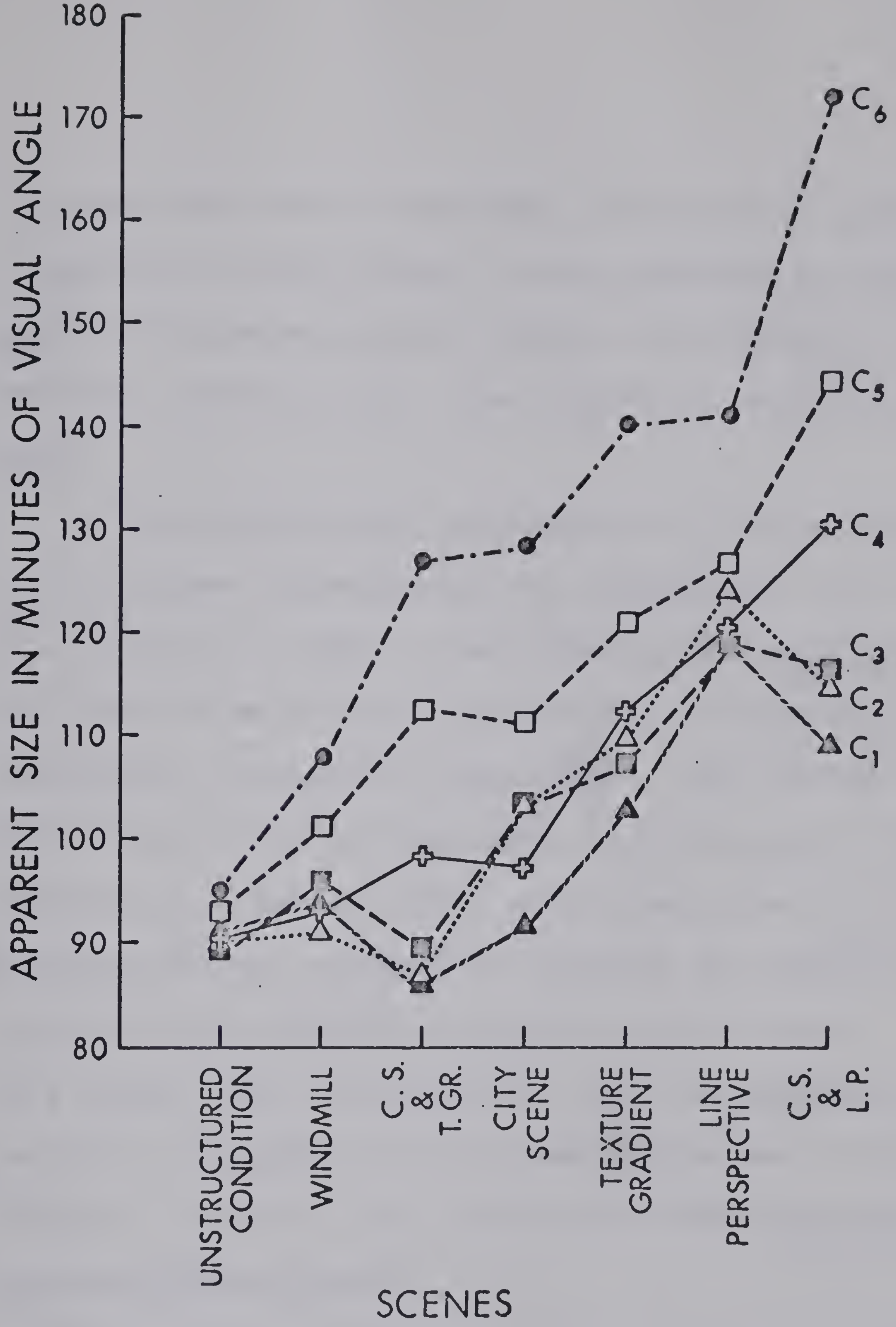
The analysis of variance (Table II) also showed the C main effect (differences due to differences in elevation of target) to be highly significant ($F = 47.379$; $df = 5,315$; $p << .005$). A Greenhouse-Geiser analysis confirmed this ($F = 47.379$; $df = 1,63$; $p << .005$). Duncan's New Multiple Range Test was therefore used to compare the effect of each elevation with that of every other over all scenes (see Table VII). Results of this test show that the horizon condition (0°0') and the elevation immediately above it (2°27') differs signficantly from each other and from the four highest elevations. In addition, the elevation two steps above the horizon (4°54') differs significantly from the highest elevation. No other significant differences were found. Graph I illustrates differences due to elevation.

Table VII

Elevation Means		C_1(12°13')	C_2(9°46')	C_3(7°21')	C_4(4°54')	C_5(2°27')	C_6(0°0')	Shortest Significant Ranges
		13879.8	14212.4	14270.4	14883.1	16240.8	18384.7	α = .05
C_1	13879.8		332.6	390.6	1003.3	2361.0	4504.9	R_2 = 906.7
C_2	14212.4			58.0	670.7	2028.4	4172.3	R_3 = 954.5
C_3	14270.4				612.7	1970.4	4114.3	R_4 = 986.9
C_4	14883.1					1357.7	3501.6	R_5 = 1010.4
C_5	16240.8						2133.9	R_6 = 1029.1

Any two treatment means not underscored by the same line are significantly different ($p < .05$).
Any two treatment means underscored by the same means are not significantly different ($p \geq .05$).

Table VII: Duncan's New Multiple Range Test applied to the differences between six elevation means (n of observations per mean = 70). Protection level (from Edwards,1965) = $(1 - \alpha)^{k-1} = (1 - .05)^{6-1} = .95^5 = 77.4\%$ (where α = significance level and k = no. of means).



Graph I: Size means in minutes of visual angle for elevations plotted over scenes under both 'Photic Gradient' and 'No Photic Gradient' conditions. (see Appendix 3 for explanation of symbols). Veridical size of the moon is thirty minutes, eight seconds.

Hypothesis One is therefore confirmed in part: a luminous circular target in the presence of any one of the aforementioned factors produced an absolute illusory size. The Discussion elaborates this point.

Of the second order interactions shown in Table II, A X C (scenes X elevations) was significant ($F = 2.728$; $df = 30,315$; $p < .005$). The effect is shown by Graph II. Results of further analysis of one aspect of the interaction is given in Table VIII. The purpose of this analysis was to determine which particular scenes produced an illusory effect over elevations. A Friedman two-way analysis of variance by ranks[1] over elevations was therefore applied to each scene. Table VIII showns that all scenes but the Unstructured Condition produced a significant change over elevations. However, the result for the Unstructured Condition approached significance.

The analysis of variance (Table II) resulted in A X B (scenes X presence or absence of photic gradient) not significant ($F = .515$; $df = 6,63$; $p > .25$). Graph III illustrates this interaction. B X C (presence or absence of photic gradient X elevations) is also not significant ($F = .520$; $df = 5,315$; $p > .25$). Graph IV,

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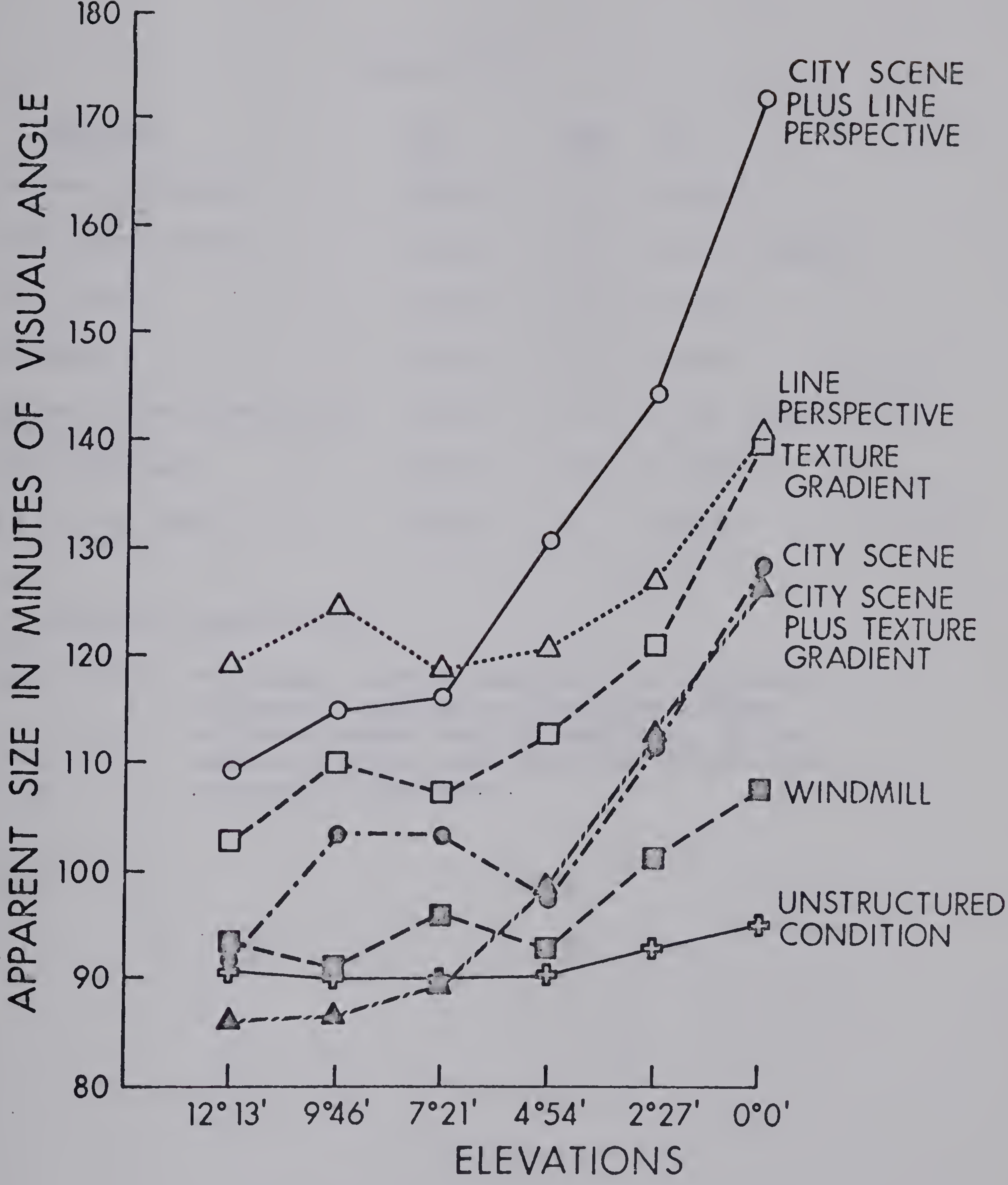
[1]from Ferguson, Statistical Analysis in Psychology and Education (1959), p. 272-274.



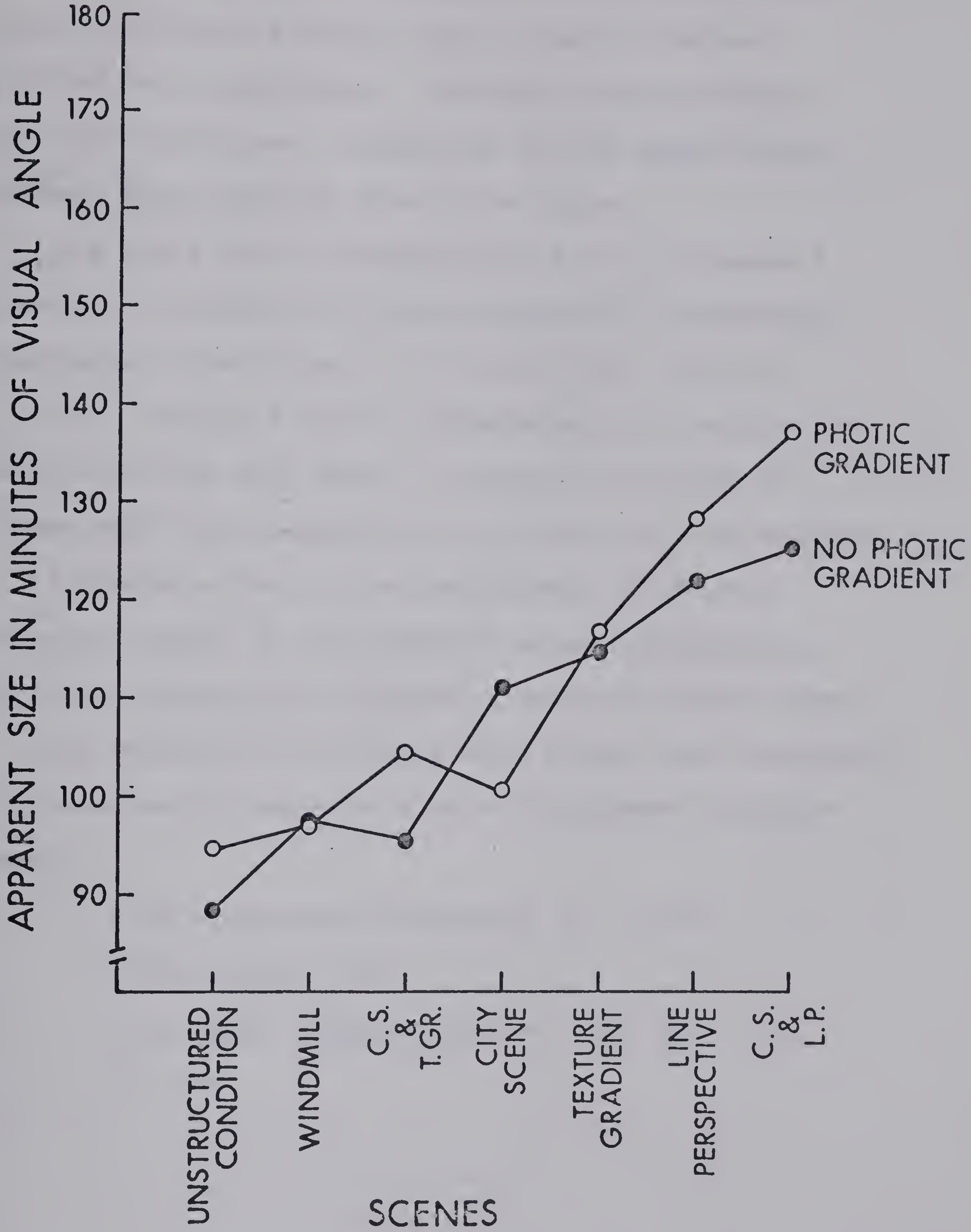
Graph II: Size means in minutes of arc for each scene plotted over elevations for both 'Photic Gradient' - 'No Photic Gradient' conditions.
Veridical size of the moon is thirty minutes, eight seconds.

Table VIII

source	χ_r^2	df	p
Texture Gradient	29.37	5	<.001*
Line Perspective	13.0	5	<.05 (≈.03)*
City Scene	27.0	5	<.001*
Windmill	25.3	5	>.001*
Unstructured Condition	10.8	5	>.05 (≈.06)
C.S. plus L.P.	33.6	5	<.001*
C.S. plus T.Gr.	36.5	5	<.001*

* indicates significance

Table VIII: Friedman two-way analysis of variance by ranks applied to test the effect of each scene over elevations. χ_r^2 is computed from data for both conditions of photic gradient.



Graph III: Size means in minutes of visual angle for conditions of gradient ('Photic Gradient' - 'No Photic Gradient') plotted over scenes.
Veridical size of the moon is thirty minutes, eight seconds.

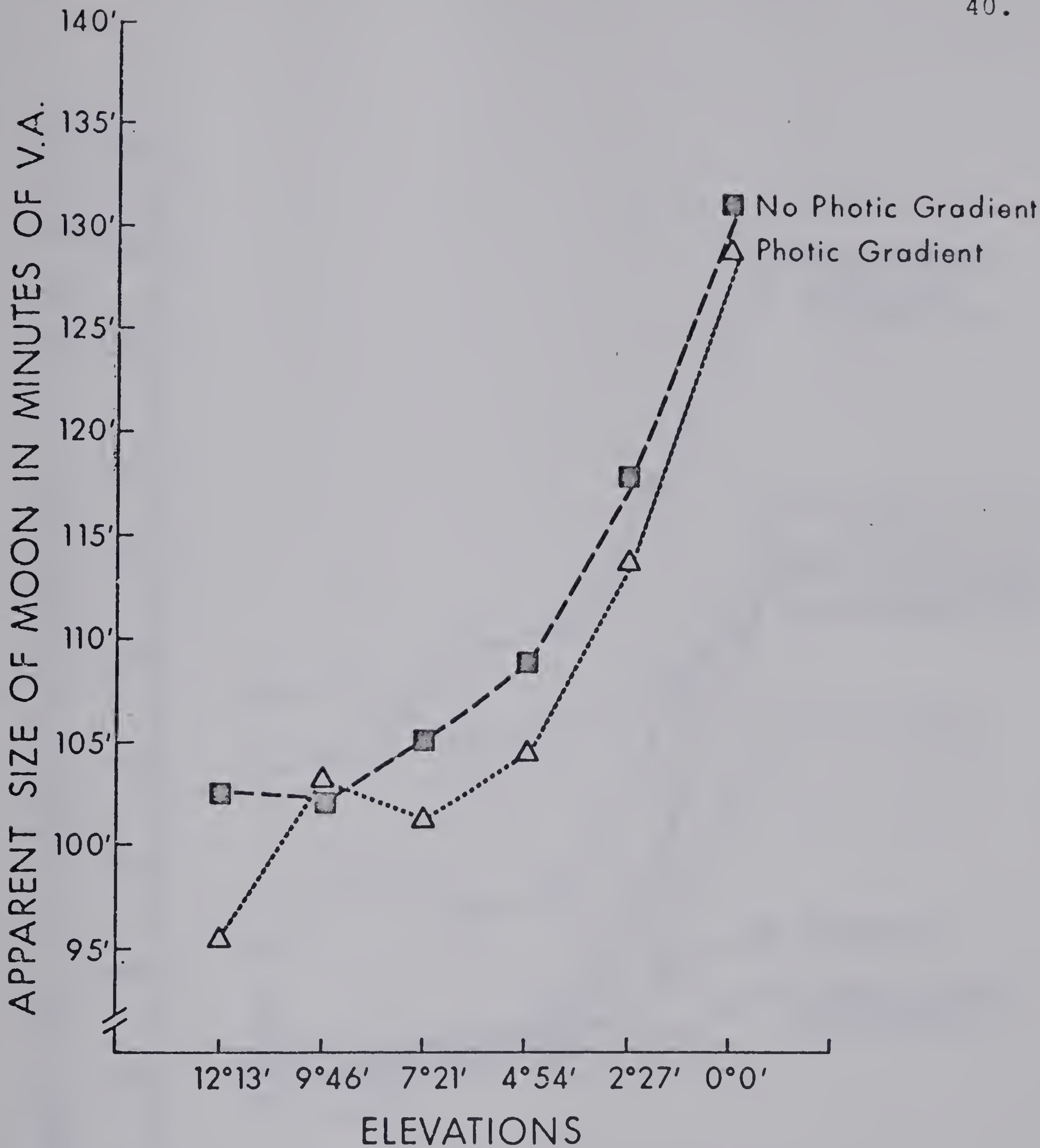
however, shows small but regular differences between means for photic gradient and no photic gradient plotted over elevations. Although relative change was not significant, inspection of the graphs shows changes from absolute size to be large.

The third order interaction A X B X C (scenes X presence or absence of photic gradient X elevations) approached significance ($F = 1.475$; $df = 30,315$; $p \approx .06$). Graphs V and VI illustrate this interaction as plotted for size means. Graphs VII through IX illustrate the interaction as plotted for size medians.

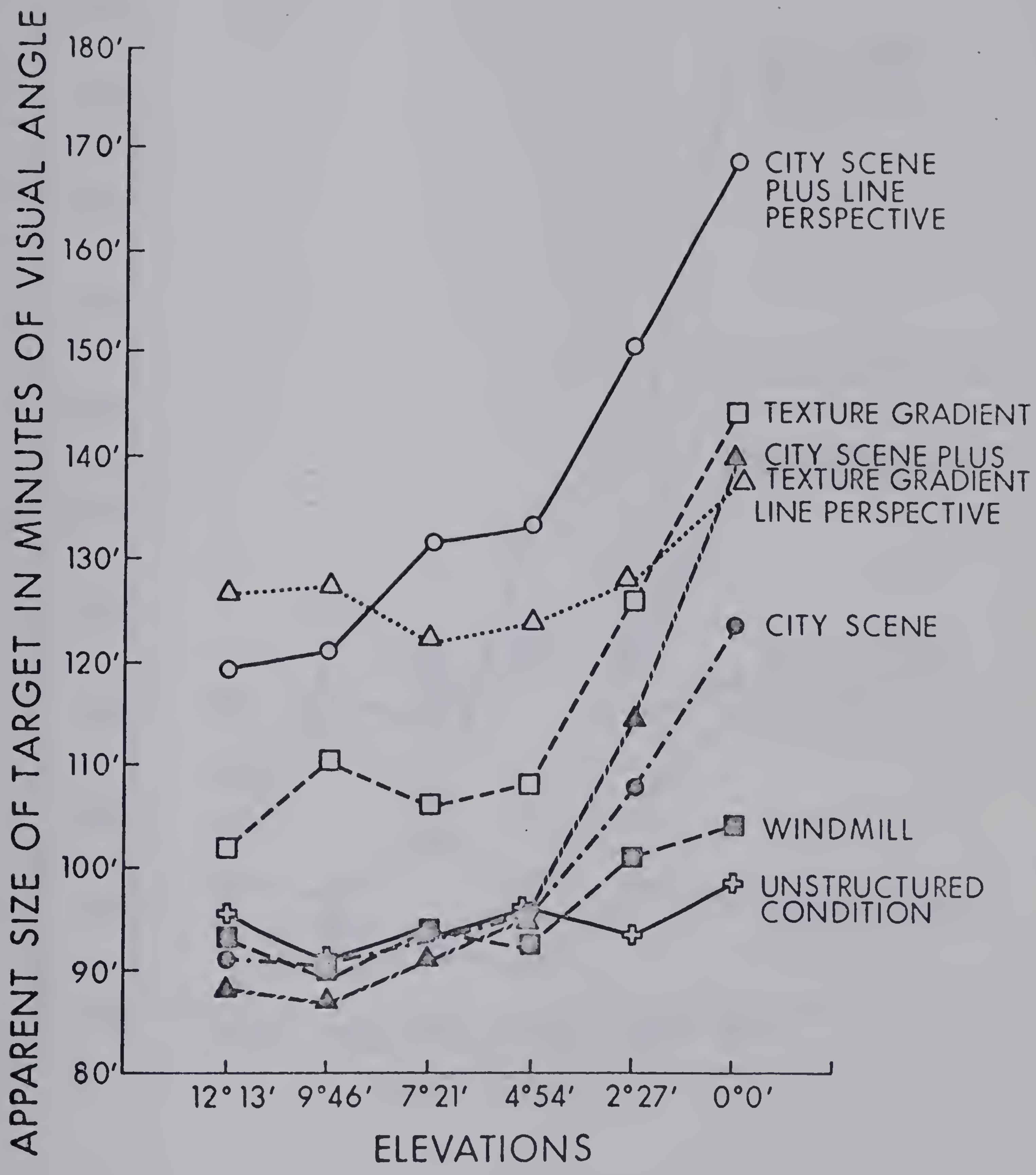
Hypothesis Two is then confirmed: a luminous circular target in the presence of any <u>combination</u> of these factors will produce absolute illusory size.

Two measures of distance were taken (see Procedure). Correlations of apparent size with apparent distance were:

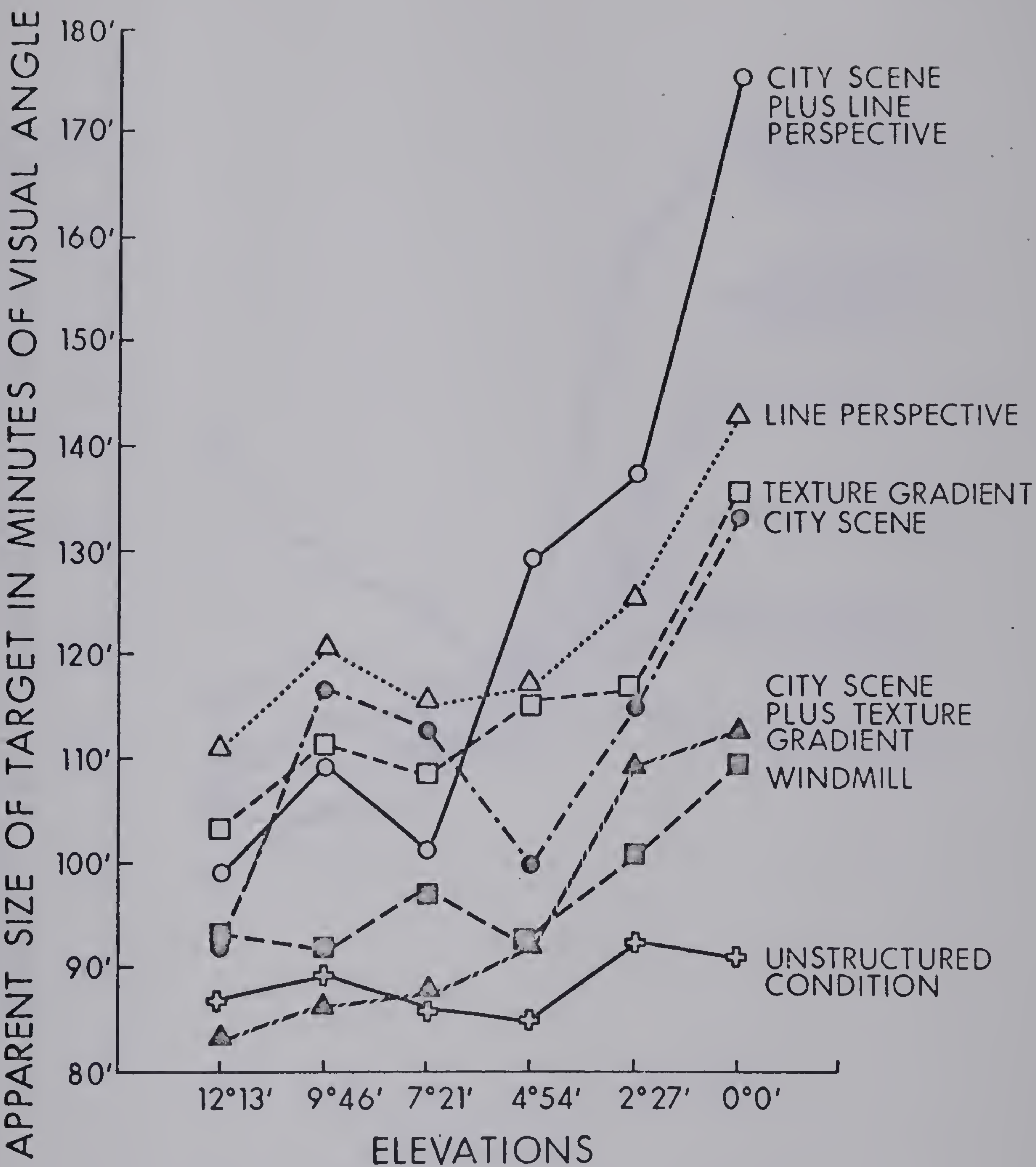
> for magnitude estimation, $r = .365$;
> $df = 13$; $p > .05$
> for depth estimation, $r = .035$; $df = 13$;
> $p > .05$



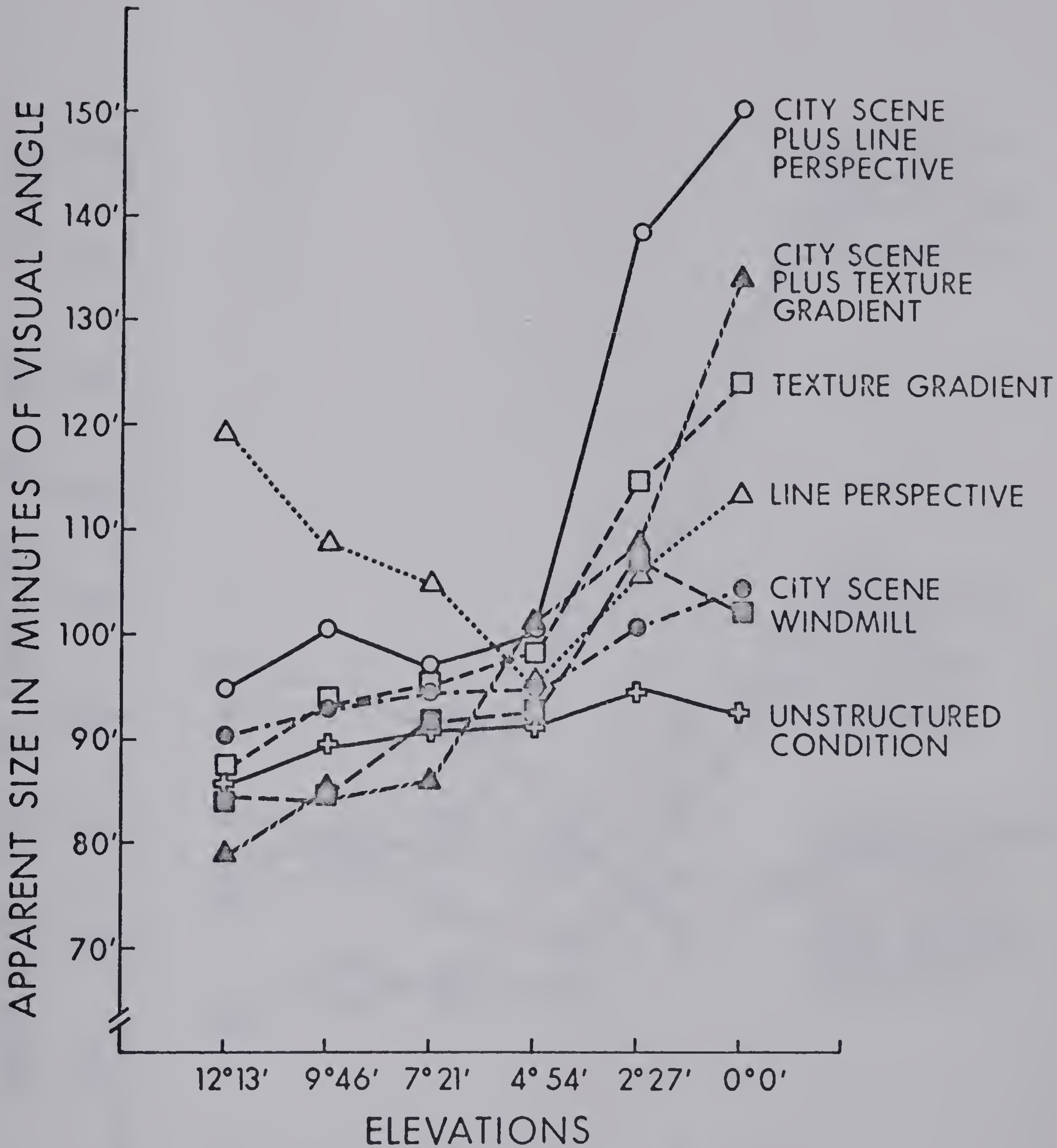
Graph IV: Size means in minutes of arc for 'Photic Gradient' and 'No Photic Gradient' plotted over elevations. Veridical size of the moon is thirty minutes, eight seconds.



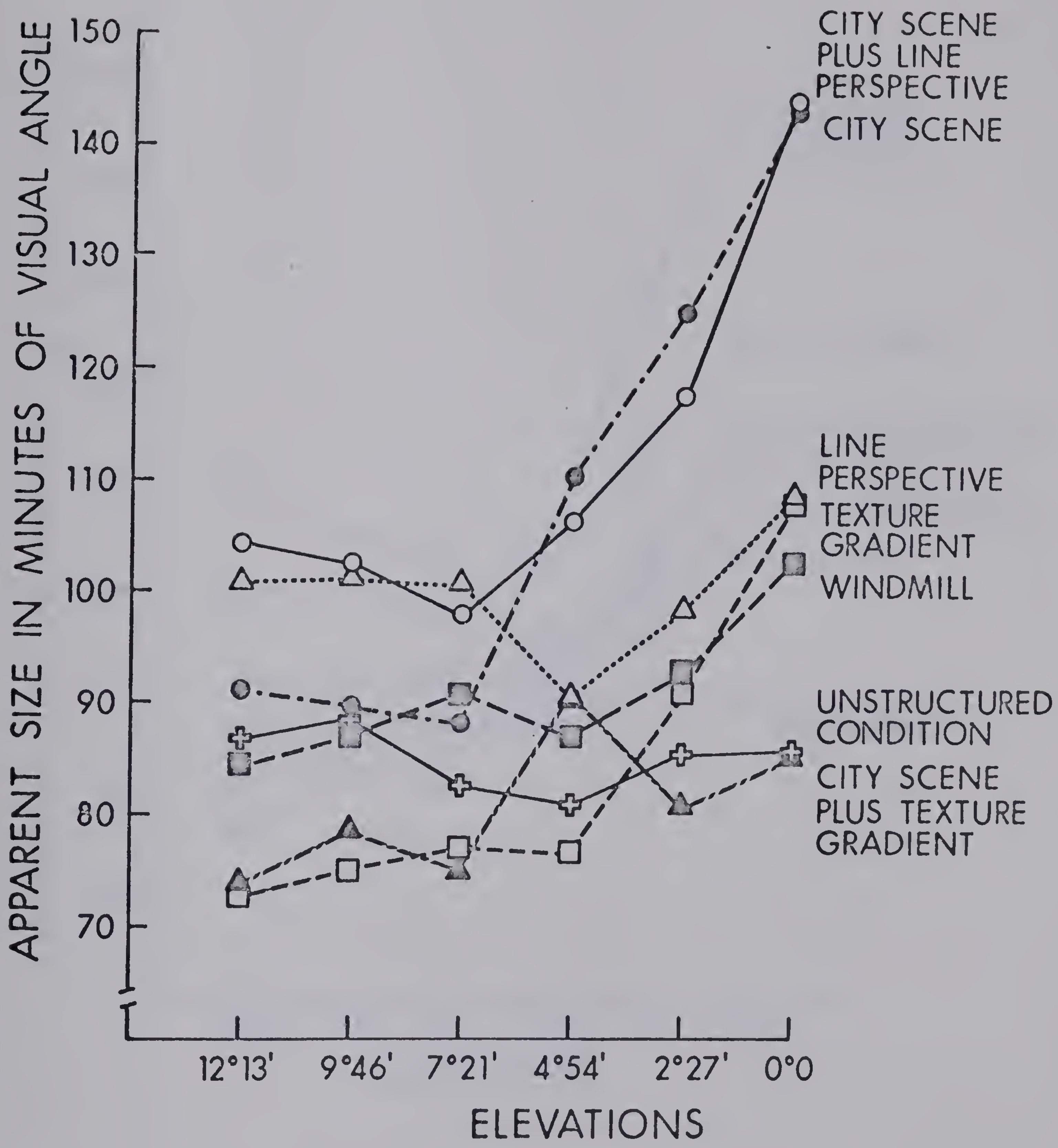
Graph V: Size means in minutes of arc for each scene plotted over elevations under 'Photic Gradient' condition. Veridical size of the moon is thirty minutes, eight seconds.



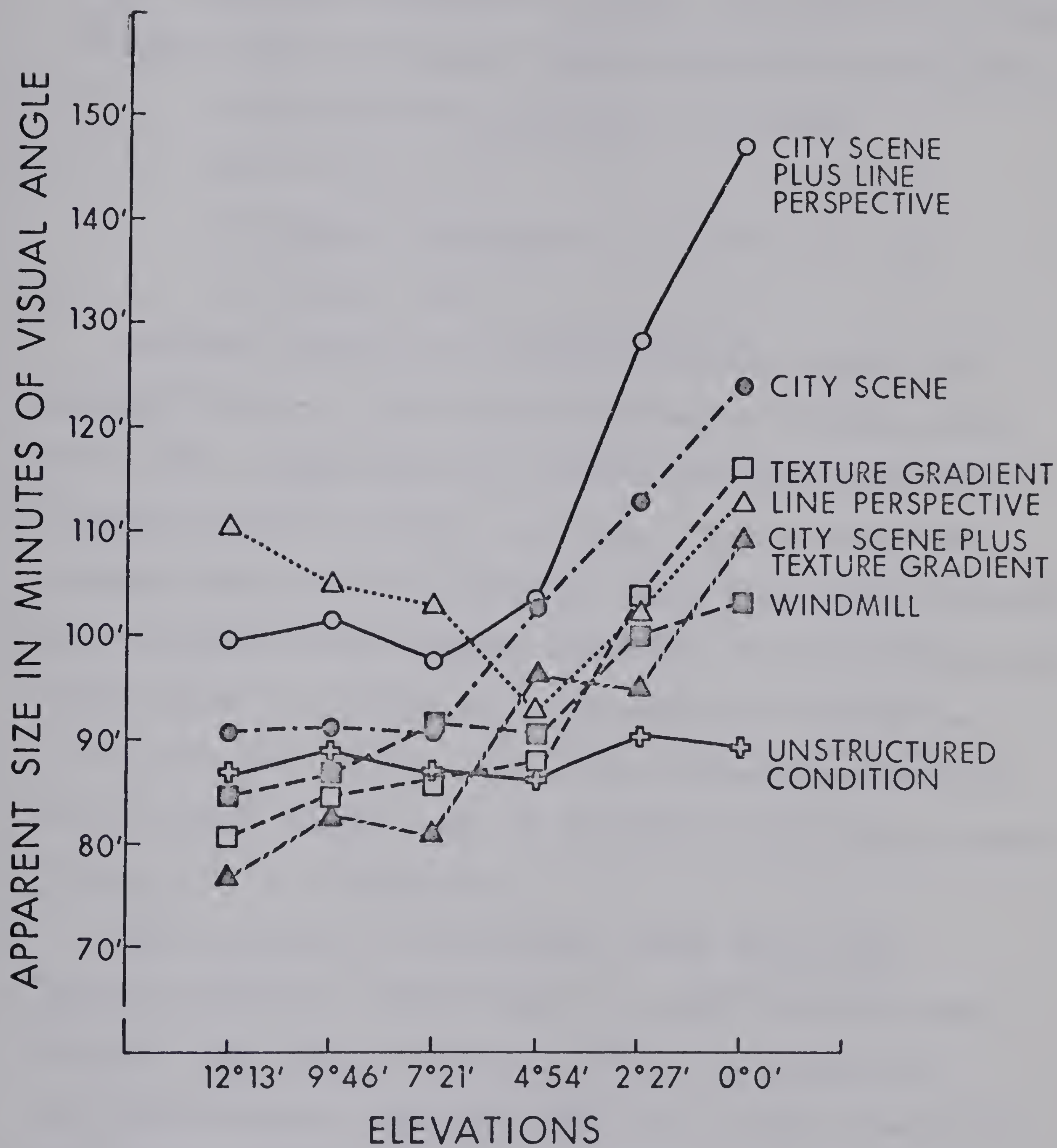
Graph VI: Size means in minutes of arc for each scene plotted over elevations under 'No Photic Gradient' condition.



Graph VII: Size medians in minutes of arc for each scene plotted over elevations under 'Photic Gradient' condition.



Graph VIII: Size medians in minutes of arc for each scene plotted over elevations under 'No Photic Gradient' condition.



Graph IX: Size medians in minutes of arc for each scene plotted over elevations under both 'Photic Gradient' - 'No Photic Gradient' conditions. (Graph VIII and Graph I differ in that the former is plotted for medians, the latter is plotted for means).

T-tests were employed to test differences between apparent distance to horizon and apparent distance to zenith for all scenes. Results were non-significant;

for magnitude estimation, $t = 1.061$; $df = 13$; $p > .15$

for depth estimation, $t = 1.464$; $df = 13$; $p > .05$ ($p \approx .07$)

Further analysis of distance measures pooled both methods, since a high correlation existed between them ($r = .88$). Based upon this pooled estimate, individual inspection of the scenes were made. This showed that Texture Gradient alone produced large differences between the horizon and the highest elevation, but this difference, when tested statistically, also proved not significant ($t = .976$; $df = 18$; $p > .15$). Line Perspective produced only a small change, and the remaining five scenes showed essentially no differences.

Rank-ordering of conditions, based again upon pooled estimates, showed that the target appeared most distant when Texture Gradient was in the foreground, and least distant when City Scene was in the foreground. The remaining five conditions were grouped in a middle range and produced moderate effects of apparent distance. When tested by a Friedman analysis, these differences proved not significant ($\chi_r^2 = 11.52$; $df = 6$; $p > .05$; [$p \approx .08$]).

The third hypothesis is discussed in the next section.

DISCUSSION

The roles of the five factors in producing illusory size of a luminous circular target were considered in this study. These are:

1. eye elevation
2. apparent distance
3. texture gradients
4. objects or cues in the field
5. brightness or photic gradient

Also, the effects of various combinations of these factors were considered, with emphasis on testing additivity of components.

The results of this study indicate that all factors tested (except apparent - distance) produced absolute illusory size i.e. target size was overestimated as a result of all conditions. The lowest average (over Ss) overestimation was greater than one hundred percent, in fact. Since all stimulus conditions increase size significantly (i.e. produce absolute illusory size), theories are not mutually dependent. Consequently, no one theory of moon size will suffice.

Size illusion as defined by previous studies is expressed as a ratio comparing the size of the moon on the horizon with size of moon at zenith (Boring, 1939, 1943; Kaufman and Rock, 1962; etc.), that is, relative illusory size. Values for this table are given in Table I. Of the three results measured by the indirect

method, the range of ratios reported by Kaufman and Rock roughly agrees with the overall ratio found in the present experiment i.e. 1.32. Kaufman and Rock, however, reported results more comparable to the present study by use of the direct method. They mention here that size indexes of around this magnitude are dependent on the presence of terrain and also upon the peculiar terrain present. Both findings are supported by the present study; in fact, ratios produced by Kaufman and Rock approximate ratios produced by this study under similar conditions of terrain. Agreement is also found under conditions where eye elevation alone is operative. Kaufman and Rock record a ratio of 1.03, slightly lower than that found in the present experiment (1.04 - 1.06).

Gruber et al (1962) report an illusion of larger magnitude (by the successive method) than the overall result of this study. It should be noted, however, that results of several conditions of terrain in the present study approximate Gruber's ratios. The size index cited by Minnaert for both the Sun and Moon Illusions is larger than that found by the present experiment. Differences may be due to the ability to effectively simulate the natural situation in the laboratory.

This experiment also contributes a test of the relative importance of factors i.e. how powerful each was in production of size illusion. Terrain characteristic proved to be the most important variable[1]. Terrain itself is a composite variable. It is comprised of texture gradients of space and objects in the scene. Some of the individual conditions of terrain do appear to be more effective than others, however. In particular, the Combination (C.S. plus L.P.) was most successful in increasing apparent size. The effects of other foregrounds are not readily apparent, either from the graphs or statistical evidence. On the whole, (from means given in Table VIII) it would appear that Texture gradient and Line Perspective are somewhat less effective than the Combination (C.S. plus L.P.) condition, but are more successful than the City Scene, which in turn, is more successful than the Combination (C.S. plus T.Gr.) condition, the Windmill condition or the Unstructured Condition.

The results produced by Line Perspective in the foreground are complex; graphing its <u>medians</u> produces a gradual decline in size judgments from highest elevation to mid-elevation followed by an increase to the horizon, thus size judgments are only slightly larger at the horizon than at the highest elevation.

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[1] see Appendix[4] for further discussion

Graphing <u>means</u> of size judgments for Line Perspective however yields the gradual increase from highest elevation to horizon found for other conditions. Since graphing the means and the medians does not produce comparable curves, the conclusion is that the effects of Line Perspective is highly variable and consequently, not interpretable as a factor.

The Windmill condition was not highly effective in producing relative illusory size; in fact, the effects of this condition differed little from the Unstructured Condition (absence of scene) in which no change in apparent size over elevations occurred. The effects found in the Windmill condition may be due to motion in the scene i.e. the difference between the effect of City Scene as composed of objects and the Windmill as an object may be due to differences in response to static and changing (in this case, moving) conditions.

The classic theory of Ptolemy states that the size of the moon is determined by cues given by the size of terrestrial objects: a theory not unlike the unconcious inference of Helmholtz. The present experiment shows that unfilled space possessing texture gradients produced a larger absolute illusion than did scenes of a city, that containing a moving windmill

and that in which a foreground was absent. The fact that combination conditions produced large size illusions is likely due to the foreground (or space-producing) conditions present. This was the more important feature in producing the effect, i.e. more important than objects in the combinations. Objects added little to the effect obtained from Line Perspective alone.

The "framing effect" of large buildings or large objects in the terrain, mentioned by Kaufman and Rock as a secondary factor in producing the illusion was not therefore confirmed by the present experiment. Although both Combination scenes contain objects, they are not considered in this comparison since other factors may be operating (see page 54-56).

Eye elevation has been invoked by Boring and Holway (1939) as the explanation for the illusory size of Heavenly Bodies. This factor appears to be independently reliable by the analysis of variance of size measures, but inspection of Graphs II and V through IX suggests that this may be an artifact arising from correlational effects over elevations. These graphs and Table VIII show the Unstructured Condition (in which eye elevation varies but terrain conditions are not operating) as producing relatively little change in apparent size over elevations. Since Boring's theory is based on

<u>changes</u> of eye elevation, this result is difficult to interpret. The presence of the target no doubt produces an absolute size change (an illusion), but changes in elevation produce only small relative size change. The conclusion drawn is that eye elevation is a relatively weak factor in varying the magnitude illusion.

The question might arise as to whether a greater range of elevation would alter this result. The present experiment of course varied elevation only from 0° 0' to 12°13'. At the first glance, the range seems small. But reference to curves presented by Boring and Holway (1939) indicates that for three observers, approximately 1/3 to 1/2 of the total size change (from elevations of 0° to 60°) was accounted for in the range of elevations employed in the present experiment.

In addition to the "framing effect", Kaufman and Rock also contend that "the illusion is based on the sense of great distance which the observer has when viewing the moon directly above the horizon[1]". The present experiment does not support this hypothesis. The low positive correlation between apparent size and apparent distance suggests little interdependence of these two variables. In addition, distance measures appear to be independent of terrain characteristic.

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[1]The Moon Illusion, II, p. 1023

However, it should be noted that differences usually found between apparent distance to horizon and apparent distance to zenith were not produced.

Although the presence or absence of the brightness gradient did not produce significant differences in relative size over elevations, it is possible that a more perfect 'no photic gradient' condition than that employed in the present experiment might have produced significance. In the present case, the 'no photic gradient' condition was composed of the target plus a small gradient which was impossible to eliminate because of the combination of surface and projection system used. Here again, although relative size was not significantly different for levels of the factor, judged size was much larger than the true size of the target, i.e. absolute illusory size was produced.

Hypothesis Two dealt with the illusory size produced by combinatins of conditions. This hypothesis was borne out, since the combination of scenes X elevations was shown to be significant, and scenes X presence or absence of photic gradient X elevations was almost significant. Further analysis of the scenes X elevations interaction showed that all scenes but Unstructured Condition produced significance differences in size over elevations, with Unstructured Condition

approaching significance. Another way to look at the interaction is to consider changes in elevation over scenes. Graph I illustrates that the four highest elevations appear to give size judgments, which, on the whole, are very similar. Any differences within conditions which do occur are in the horizon condition and the elevation immediately above it. Further evidence for this point is cited in Table VII. Therefore, since no change in elevation occurs when there is no foreground present, this effect is likely an interaction of elevations with scenes. The remaining two combinations (scenes X presence or absence of photic gradient and eye elevation X presence or absence of photic gradient) were not successful in increasing illusory size (unless size judgments are again considered in relation to the absolute size of the target).

Hypothesis Three dealt with additivity of effects. It is in part borne out, based on graphic evidence. (Statistical evidence is complicated by non-randomization of scenes over Ss.[1]) Based on Graph IX which plots the medians (and is therefore more independent of individual differences than means), the Combination

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[1]see Appendix 5

(C.S. plus L.P.) appears to be composed of an additive effect of City Scene and Line Perspective, although this result is not clear-cut, due to the peculiar direction and shape of the Line Perspective curve. The additive effect can also be shown graphically by extrapolation of Graph V. When extrapolation is performed, the point at which City Scene condition and Line Perspective condition converge, is the same as that at which the Combination (C.S. plus L.P.) condition and City Scene condition converge, so far as the apparent size axis is concerned. This combination of effects indicates that in the Combination condition, City Scene was a very weak factor, while Line Perspective was dominant in producing the size effect.

The two mentioned points of convergence did not coincide on the abscissa (degrees of elevation), however. Instead, the Combination (C.S. plus L.P.) and City Scene converge at a point considerably less than the point of approximate true zenith where City Scene and Line Perspective converge. This may be interpreted to show that the Combination (C.S. plus L.P.) served to bring the true zenith phenomenally closer, and thus may have evoked the "Vault of Heavens" effect. In contrast, the Texture Gradient, City Scene and Combination (C.S. plus T.Gr.) all converged in approximately the

same place on both abscissa and ordinate, suggesting no "Vault of Heavens" effect. In fact, an opposite process appears to be acting in the Combination (C.S. plus T.Gr.) condition. From Graph IX, it would appear that, on the whole, a gross subtractive effect is in operation. Consideration of these two major factors (objects in the scene and texture gradients) in the make-up of terrain leads to the conclusion that Hypothesis Three is, in a gross way, partially supported.

SUMMARY

In sum, it appears that all conditions are effective in producing size when judged size as compared to the absolute size of the target is considered, i.e. <u>absolute</u> illusory size. However, when <u>relative</u> illusory size is considered (see Glossary), only representation of terrain in the field produced significant illusory size; in fact, both aspects of terrain, i.e. texture gradients and objects in the field, produced illusory size. Eye elevation, apparent distance, and the presence of the photic gradient did not affect relative illusory size.

Since absolute illusory size is produced in all experimental conditions,further discussion of the relative importance of each factor i.e. how powerful each was in producing the illusion, is relevant. Within conditions, terrain characteristic is the prepotent variable. In particular, texture gradients of space are relatively more important than objects in the scene. Still, terrain characteristic is clearly not a sufficient explanation, since the presence of the target in an unstructured field produces an illusion, and other factors tested also produce size judgments larger than the veridical target size. Eye elevation and the brightness or photic gradient must also be considered

in discussion of the illusion, although they are less powerful factors than terrain characteristics. Important as terrain characteristics were, had experimental conditions allowed for elevation of the "moon" through an arc to true zenith, effects found in the present experiment might have been altered, particularly with respect to the role of eye elevation, and detail would surely have been expanded. The final factor, apparent distance, appears to be an ineffective factor in the present study. In the present experiment, a method of indirect measurement or successive comparison was employed in size estimation. Future researchers should utilize not only this method, but should also measure size by the direct method i.e. simultaneous comparison, in order to determine whether the peculiar method employed affects results.

Many answers have been given the question, Why does the moon appear larger when at the horizon than when at the zenith? Implicit in these attempts is the supposition that some single fact or explanation will account for the variance. This does not appear to be so. The illusion may be evoked by any one of several conditions or combinations of conditions. The traditional theoretical approachs may each be based upon a single false premise.

REFERENCES

Adams, W. S. An Introduction to APL/360, Department of Computing Science, U. of A., Edmonton, No. 7, 1967.

Andreas, B. Experimental Psychology, John Wiley and Sons, Inc., N.Y., 1960, 16-23, 282-285.

Baird, J. C., Gulick, W. L. and Smith, W. M. The effects of angle of regard upon the size of after-images, Psychol. Rec., 1962, 12, 263-271.

Bartley, S. H. Beginning Experimental Psychology, McGraw-Hill, N.Y., 1950, 136-138.

Bartley, S. H. Principles of Perception, Harper and Row, N.Y., 1958.

Berkeley, G. An Essay Towards A New Theory of Vision, (Scribner's, New York, rev. ed., 1929), sections 67-78.

Boring, E. G. A History of Experimental Psychology, 1929, Appleton-Century-Crofts, N.Y., 308-315.

Boring, E. G. The Moon Illusion, Amer. J. Physics, 1943, 11, 55-60.

Boring, E. G. Psychologist at Large, 1961, Basic Books, N.Y., 115-126.

Carlson, V. R. Size - constancy judgments and perceptual compromise, J. Exp. Psychol., 1962, 63, 68-73.

Chalmers, E. L. Jr. Monocular and binocular cues in the perception of size and distance, Amer. J. Psychol., 1952, 65, 415-423.

Crookes, T. G. The apparent size of after-images, Amer. J. Psychol., 1959, 72, 547-553.

Day, R. H. Perception, Annual Review of Psychol., 1965, 16, 1-28.

Edwards, A. L. Experimental Design in Psychological Research, Holt, Rinehart and Winston, N.Y., 1965.

Edwards, W. and Boring, E. G. What is Emmert's Law? Amer. J. Psychol., 1951, 64, 416-422.

Epstein, W. The known-size-apparent-distance hypothesis, Amer. J. Psychol., 1961, 74, 333-346.

Epstein, W., Park, J. and Casey, A. The current status of the size-distance hypotheses, Psychol. Bull., 1961, 58, 491-514.

Ferguson, G. A. Statistical Analysis in Psychology and Education, McGraw-Hill, York, P.A., 1959, 272-274.

Gibson, J. J. The Perception of the Visual World, Houghton Mifflin Co., Boston, 1950.

Gibson, J. J. The Senses Considered as Perceptual Systems, Houghton Mifflin Co., Boston, 1966.

Gibson, J. J. and Flock, H. The apparent distance of mountains, Amer. J. Psychol., 1962, 75, 501-503.

Gogel, W. C., Wist, E. R., and Harker, G. S. A test of the invariance of the ratio of perceived size to perceived distance, Amer. J. Psychol., 1963, 76, 537-553.

Goldstein, G. Moon Illusion: an observation, Science, 1962, 138, 1340.

Gruber, H., King, W. and Link, S. paper presented at the meeting of the Eastern Psychological Association, N.Y., April, 1960.

Hastorf, A. H., and Kennedy, J. L. Emmert's law and size-constancy, Amer. J. Psychol., 1957, 70, 114-116.

Helmholtz, H. von Physiological Optics, Southall, 1925, 3, 290-292, 360-362, 369-370.

Hochberg, J. Perception, Foundations of Modern Psychology Series, Prentice-Hall, N.J., 1964, 19, 25, 51-57, 76-82.

Holway, A. H. and Boring, E. G. The Moon Illusion and the angle of regard, Amer. J. Psychol., 1940, 53, 109-116.

Holway, A. H. and Boring, E. G. The apparent size of the moon as a function of the angle of regard: further experiments, Amer. J. Psychol., 1940, 53, 537-553.

Holway, A. H. and Boring, E. G. Determinants of apparent visual size with distance variant, Amer. J. Psychol., 1941, 54, 21-37.

Hurvich L. M. and Jameson D. The Perception of Brightness and Darkness, Allyn and Bacon, Boston, 1966, 2-6.

Ittelson, W. H. The constancies in perceptual theory, Psychol. Rev., 1951, 58, 285-294.

Ittelson, W. H. Visual Space Perception, Springer, N.Y., 1960.

Ittelson, W. H. and Kilpatrick, F. P. Experiments in perception, Sci. Amer. Reprints, W.H. Freeman and Co., Aug., 1951, No. 405.

Kaufman, L. and Rock, I. The Moon Illusion, Sci. Amer., 1962, 207, 120-130.

Kaufman, L. and Rock, I. The Moon Illusion, I, Science, 1962, 136, 953-961.

Kilpatrick, F. P. and Ittelson, W. H. The size-distance invariance hypothesis, Psychol. Rev., 1953, 60, 223-231.

King, W. and Gruber, H. Moon Illusion and Emmert's Law, Science, 1962, 135, 1125-1126.

Koffka K. Principles of Gestalt Psychology, Routledge and Kegan Paul, London, 1935.

Minnaert, M. The Nature of Light and Colour in the Open Air, 1954, Dover Publications Inc., N.Y.

Osaka, R. Celestial Illusion - an overview of the history of theories, Psychologica, 1962, 5, 24-31.

Over, R. Brightness judgments and stimulus size and distance, Brit. J. Psychol., 1962, 53, 431-438.

Oyama, T. The effect of hue and brightness on the size-illusion of concentric circles, Amer. J. Psychol., 1962, 75, 45-55.

Prentice, W. C. H. The relation of distance to apparent size of figural after-effects, Amer. J. Psychol., 1947, 60, 617-623.

Price, G. R. An Emmert's Law of apparent sizes, Psychol. Rec., 1961, 11, 145-151.

Rock, I. and Kaufman, L. The Moon Illusion, II, Science, 1962, 136, 1023-1031.

Swartz, P. Psychology; The Study of Behavior, Van Nostrand, Toronto, Canada, 1963, 252-260.

Wohlwill, J. R. The perspective illusion: perceived size and distance in fields varying in suggested depth, in children and adults, J. Exp. Psychol., 1962, 64, 300-310.

Woodworth, R. S. and Schlosberg, H. Experimental Psychology, Holt, Rinehart and Winston, N.Y., 1964, 484-486.

A P P E N D I C E S

APPENDIX 1

Rejection of an S's data was based on variability in judgment. The criterion employed was calculated as follows.

As mentioned previously (see Procedure), S was given five trials for each of six elevations, (thirty trials under each condition of gradient). For the initial condition (no photic gradient), the range for the five trials was calculated for each elevation. This yielded six numbers representing ranges for each elevation. A mean of these numbers was then computed. If the mean range equalled or exceeded ninety minutes of visual angle, Ss data was not used in the analysis.

As the possible range of judgments was small (approximately one half (1/2) degree to seven (7) degrees), an average range of one and one half (1 1/2) degrees seemed a reasonable criterion for rejection. Employing this average range as a criterion resulted in the rejection of approximately thirteen per cent of the Ss.

APPENDIX 2

Additional apparatus was initially employed to measure size by a second method of successive comparison, but this method was dispensed with after S_{15}, due to difficulties inherent in the apparatus. This apparatus consisted of rectangular brass plates containing circular aperatures of varying diameters which differed by 1/4 inch between plates with larger aperatures and by 1/8 inch between plates with smaller aperatures. This graduation did not seem to be adequate in terms of diminuation since S would consistently chose the same plate on each trial. Over Ss, there was also very little variation in choice of plates.

APPENDIX 3

Size data from the present experiment was arranged in a split-split plot design (see Table IX), and then placed in fourteen convenient matrices (see Table X) in order that an analysis of variance might be run by APL. Table X presents the raw data as arranged in these matrices. Inset shows their position in Table II.

A represents varying scenes (see Figures III to IX).

A_1 refers to the City Scene plus Line Perspective combination

A_2 represents the Windmill Scene

A_3 represents the Line Perspective Scene

A_4 represents the City Scene plus Texture Gradient combination

A_5 represents the Unstructured Condition

A_6 represents the Texture Gradient scene

A_7 represents the City Scene condition

(Order of scenes is arbitrary and represents only the order in which data was typed into APL).

B represents the photic gradient factor (see Figures VI and VII).

B_1 represents 'No Photic Gradient' condition

B_2 represents 'Photic Gradient' condition

C represents varying, equally-spaced conditions of elevation.

C_1 represents an angle of 12°13' from S's sensible horizon

C_2 represents an angle of 9°46'

C_3 represents an angle of 7°21'

C_4 represents an angle of 4°54'

C_5 represents an angle of 2°27'

C_6 represents an angle of 0°00' (the horizon position).

Table IX

		(B$_1$) No Photic Gradient						(B$_2$) Photic Gradient					
		C_1	C_2	C_3	C_4	C_5	C_6	C_1	C_2	C_3	C_4	C_5	C_6
City Scene plus Line Perspective	(A_1)												
	S_1												
	S_{10}												
Windmill	(A_2)												
	S_1												
	S_{10}												
Line Perspective	(A_3)												
	S_1												
	S_{10}												
City Scene plus Texture Gradient	(A_4)												
	S_1												
	S_{10}												
Unstructured Condition	(A_5)												
	S_1												
	S_{10}												
Texture Gradient	(A_6)												
	S_1												
	S_{10}												
City Scene	(A_7)												
	S_1												
	S_{10}												

Table IX: Size data as arranged for analysis in a split-split plot design containing seven levels of A (foreground conditions), ten S's within each A, two levels of B (Photic Gradient vs. No Photic Gradient), and six levels of C (elevation).

A1B1

Table XI

A_1(C.S. plus L.P.)* B_1 (No Photic Gradient)

	$\underline{C}_1$	$\underline{C}_2$	$\underline{C}_3$	$\underline{C}_4$	$\underline{C}_5$	$\underline{C}_6$
S_2	109.7	93.5	108.4	108.8	159.6	212.9
S_{10}	60	66.8	66.2	63.6	98.2	142.1
S_{17}	109.2	107.7	118	127.5	188.3	206
S_{27}	170.2	233.5	139.3	310.6	193.2	252.7
S_{31}	67.4	83.1	72.3	86.6	98.2	136.6
S_{41}	103.3	112.8	87.6	96.9	124.2	133.2
S_{43}	73.9	82.8	79.3	104.3	108.8	146.6
S_{51}	105.2	107.4	125.9	118.4	112	131.7
S_{59}	112.1	119	131.8	173.9	186.8	262.2
S_{66}	79.3	82.8	84.4	100.9	101.9	135.3

A1B2

A_1(C.S. plus L.P.)* B_2 (Photic Gradient)

	$\underline{C}_1$	$\underline{C}_2$	$\underline{C}_3$	$\underline{C}_4$	$\underline{C}_5$	$\underline{C}_6$
S_2	163.4	124.8	125.3	116.2	165.2	182.4
S_{10}	78.4	67.4	76.1	70.6	84	88.4
S_{17}	134.8	133.4	132.6	136.3	163.9	173
S_{27}	246.1	255.7	278.3	287.5	328	370.2
S_{31}	78.1	70.3	84	102.1	109.7	135.3
S_{41}	78.5	84.4	89.5	76.3	95.1	93.7
S_{43}	79	65.4	85.6	92.8	160.5	164.5
S_{51}	104.4	116.8	104.4	91.5	101.4	133.4
S_{59}	149.4	215.7	253.4	260.5	180.2	211.4
S_{66}	85.3	80.3	87.6	98.9	117	137.4

*refers to City Scene plus Line Perspective

A2B1

A_2 (Windmill) B_1 (No Photic Gradient)

	C_1	C_2	C_3	C_4	C_5	C_6
S_3	112.9	115	119.6	114.6	106.2	120.2
S_{13}	87.6	90	87	86.7	91	89
S_{18}	163.1	173.8	184	167.1	194.6	191.3
S_{28}	80.4	85.4	83	88.7	92.4	107.9
S_{35}	60.9	57.7	59.1	61.7	58.9	66
S_{42}	60.7	58.4	65.4	58.2	75.1	90.4
S_{45}	132.4	109.4	122.7	113.3	112.4	140.4
S_{52}	82.2	76.3	94.9	65.2	92.4	97.4
S_{62}	88.2	89.7	96.4	105	119.1	132.1
S_{70}	66.8	65.9	65.9	66.5	66.4	67.3

A2B2

A_2 (Windmill) B_2 (Photic Gradient)

		C_2	C_3	C_4	C_5	C_6
S_3	114.8	116	116.5	115.4	115.4	118.8
S_{13}	87.4	89.1	92.9	89.2	89.8	107.3
S_{18}	178.1	172.2	169.6	151	168.6	162.9
S_{28}	81.9	83.8	84.6	87.1	90.6	90.3
S_{35}	64.2	56.7	60.2	51.2	55.3	59.4
S_{42}	55.8	50	52.1	58.2	67.8	83.1
S_{45}	122.1	103.4	110.1	115.3	120.7	133.8
S_{52}	75.1	78.3	76.8	95.8	108.3	105.6
S_{62}	84.1	82.8	99	106.8	139.3	125
S_{70}	71.4	69.2	69.7	67.4	69.7	70.5

A3B1

A_3 (L.P)* B_1 (No Photic Gradient)

	$\underline{C}_1$	$\underline{C}_2$	$\underline{C}_3$	$\underline{C}_4$	$\underline{C}_5$	$\underline{C}_6$
S_1	98.8	105.5	103.4	111.9	106.2	126
S_9	104.6	101.4	104.6	102.3	101.8	109.8
S_{15}	189.4	248.2	219.5	227.8	322.8	408.6
S_{23}	51.6	64.4	51.3	56	47.1	54.9
S_{30}	80.9	78.2	77.4	83	95.8	107.7
S_{38}	109.2	81.6	84.4	81.5	97.7	103.7
S_{46}	75.6	101.8	119.4	65.5	99.5	78.6
S_{53}	58.2	56.3	59.7	61.1	60.5	52.9
S_{61}	102.4	131.5	97.7	97.5	91.5	153.8
S_{65}	249.8	236.1	236.8	281.2	236.8	292.3

A3B2

A_3 (L.P)* B_2 (Photic Gradient)

	$\underline{C}_1$	$\underline{C}_2$	$\underline{C}_3$	$\underline{C}_4$	$\underline{C}_5$	$\underline{C}_6$
S_1	115.5	118.1	119.4	126.8	129.2	140.7
S_9	106.5	108.5	105.2	101.6	111.2	117.2
S_{15}	215	223.6	220.6	211.2	220.9	261.8
S_{23}	74.3	93.5	62.2	61.8	69.8	72.9
S_{30}	74.2	77.5	78.3	85.4	98.4	110.7
S_{38}	128.4	112.6	109.5	89.2	102	79.5
S_{46}	75.2	84.9	73.8	73.9	67.3	90.2
S_{53}	62.5	56.1	64.9	59.1	59.2	74
S_{61}	113.2	108.8	106.1	142	137.8	148.2
S_{65}	310.2	298.2	294.4	295.7	294	296.1

*refers to Line Perspective

A4B1

A_4 (C.S. plus T.Gr.)* B_1 (No Photic Gradient)

	C_1	C_2	C_3	C_4	C_5	C_6
S_6	63.8	68.1	75.1	81.4	82.7	89.3
S_{14}	107	123.4	108.4	101.6	133.9	130.2
S_{19}	78.9	88.4	85.9	100.7	79.9	68.3
S_{25}	99.3	98.2	100.6	127.2	184.8	217.9
S_{34}	66.2	63.2	72.1	73.9	67.2	81.3
S_{39}	69.2	63.2	72.4	64.7	75.7	78.9
S_{49}	49.6	49.1	51.4	52.9	62.9	61.1
S_{50}	107.6	108.1	116.1	120.2	168.5	204.9
S_{57}	147.3	147.6	142.9	147	188.9	146
S_{68}	47.4	52	51.8	53.2	53.7	56.6

A4B2

A_4 (C.S. plus T.Gr.)* B_2 (Photic Gradient)

	C_1	C_2	C_3	C_4	C_5	C_6
S_6	63.8	70.5	75	90.9	99	111.2
S_{14}	132.1	103.6	111.6	112	122.9	157.5
S_{19}	78.6	83.5	86.7	110.5	118.2	160.5
S_{25}	79.9	86.5	106.8	131	151.1	223.8
S_{34}	86.8	92	85.8	92	87.8	101.9
S_{39}	59.3	57.5	62	68.2	80.9	103
S_{49}	128.9	117.6	126	151.1	190.9	245.8
S_{50}	115.2	109	122.7	133.1	150.8	192.2
S_{57}	74.6	82.5	78.2	91	80	93
S_{68}	63.6	63.2	63.2	69.9	70.4	72.9

*refers to City Scene plus Texture Gradient

A5B1

A_5(U.C.)* B_1 (No Photic Gradient)

	C_1	C_2	C_3	C_4	C_5	C_6
S_5	101.8	88.2	85	76.9	79.3	76.9
S_{11}	63.4	68.7	67.1	71.6	76.3	87.2
S_{21}	51.9	49.6	56.8	56	55.4	65.6
S_{26}	85.5	83.5	83.1	78.2	86.5	79.9
S_{32}	94.7	89.5	88	85.8	87.8	90.6
S_{37}	125	127.6	139.7	125.4	145.6	127.7
S_{48}	88.4	93.1	82.6	83.1	94.4	96
S_{54}	67	88.9	71.3	108.8	85	84.8
S_{58}	112.9	133.9	116	94.7	136.3	137.5
S_{64}	74.2	69.4	73	66.4	76.9	66

A5B2

A_5(U.C.)* B_2 (Photic Gradient)

	C_1	C_2	C_3	C_4	C_5	C_6
S5	106.8	103.6	97.4	75	98.8	91.6
S11	75.6	70	79.7	77.4	89.2	87.3
S21	57.2	54.7	60.3	63	57.3	67.3
S26	87.6	82.8	89.9	83.9	87.6	86.6
S32	84.5	85.6	86.7	90	88.2	88
S37	118.6	124	127.5	129.2	131	139.6
S48	101.5	94.9	92.1	97.7	96.9	94.3
S54	82.1	92.3	96.9	110.2	96.6	122.4
S58	151.4	114.6	120.7	138	101.2	105.3
S64	84.1	83.8	86.8	92.5	92.2	105.8

*refers to Unstructured Condition

A6B1

A_6(T.Gr.)* B_1 (No Photic Gradient)

	C_1	C_2	C_3	C_4	C_5	C_6
S_4	75.2	76.2	74.6	73.7	79.7	92.6
S_8	53.8	51.8	56.9	50.2	53.8	76.6
S_{20}	61.5	65.5	67.9	77.3	84.7	92.8
S_{24}	216.1	268	231.5	282.8	248.8	279.1
S_{29}	101.4	145.8	111.8	117.2	129.9	149.8
S_{36}	71.6	75.2	80.1	76.1	98.6	123.8
S_{44}	60.8	37.9	53.8	52.7	60.7	51
S_{56}	54.9	54.1	57.5	55.7	59	89.6
S_{63}	87	90.8	93.9	97.5	106.8	156.4
S_{69}	248.4	248.6	257.8	277.2	240	246.3

A6B2

A_6(T.Gr.)* B_2 (Photic Gradient)

	C_1	C_2	C_3	C_4	C_5	C_6
S_4	81	83	78.1	97.6	75.2	81.8
S_8	60.9	57.8	51.7	47.2	72	70.3
S_{20}	93.6	98.6	110.8	100.4	125.3	138.8
S_{24}	141.6	146.7	141.6	136.5	214.2	222
S_{29}	107.2	133.9	107.7	111.6	152.3	242.3
S_{36}	80.2	88.2	83.5	85.2	104.7	109.5
S_{44}	47.2	48.2	49.2	46.2	49.3	46.3
S_{56}	59.5	59.8	58.4	60.6	64.1	62
S_{63}	114.5	99.8	116.8	115.2	132.3	185.6
S_{69}	244.6	290.4	274.6	294	279.9	290.4

*refers to Texture Gradient

A7B1

A_7(C.S.)* B_1 (No Photic Gradient)

	C_1	C_2	C_3	C_4	C_5	C_6
S_1	45.1	45.2	45.6	45.4	55.6	74.7
S_{12}	74.2	89	93.5	128.3	172.8	210.3
S_{16}	115	116.2	82.2	108.1	141.3	153.8
S_{22}	76.4	71	72	68.7	74.1	73.3
S_{33}	120.2	129.5	128	112.4	135	133.2
S_{40}	125.7	125.7	125.7	133.7	167	216.7
S_{47}	171.6	188.3	195	192.3	185.9	195
S_{55}	30.9	30.4	36.4	39.1	37.7	48.8
S_{60}	53.2	57	65.1	55.9	63.5	64.6
S_{67}	105.8	90.8	107.7	112.1	115.6	159.9

A7B2

A_7(C.S.)* B_2 (Photic Gradient)

	C_1	C_2	C_3	C_4	C_5	C_6
S1	49	48	49.9	51.3	54.7	76.7
S12	87.2	91.3	112.3	127.5	166.3	210.3
S16	98	105.5	93	93.2	106.8	108.1
S22	74.2	67.9	68.3	69.1	73.9	77.3
S33	93.2	93.8	96	98	96.3	101.6
S40	131.8	133	122.4	129.6	165.5	226.5
S47	193.5	192.8	193.2	193.3	191.9	190.6
S55	29.6	25.8	29	31.4	42.1	45.9
S60	54.5	54.6	57.2	54.7	59	54.7
S67	103.4	97.1	116.8	103.2	131.8	151.5

*refers to City Scene

Table X

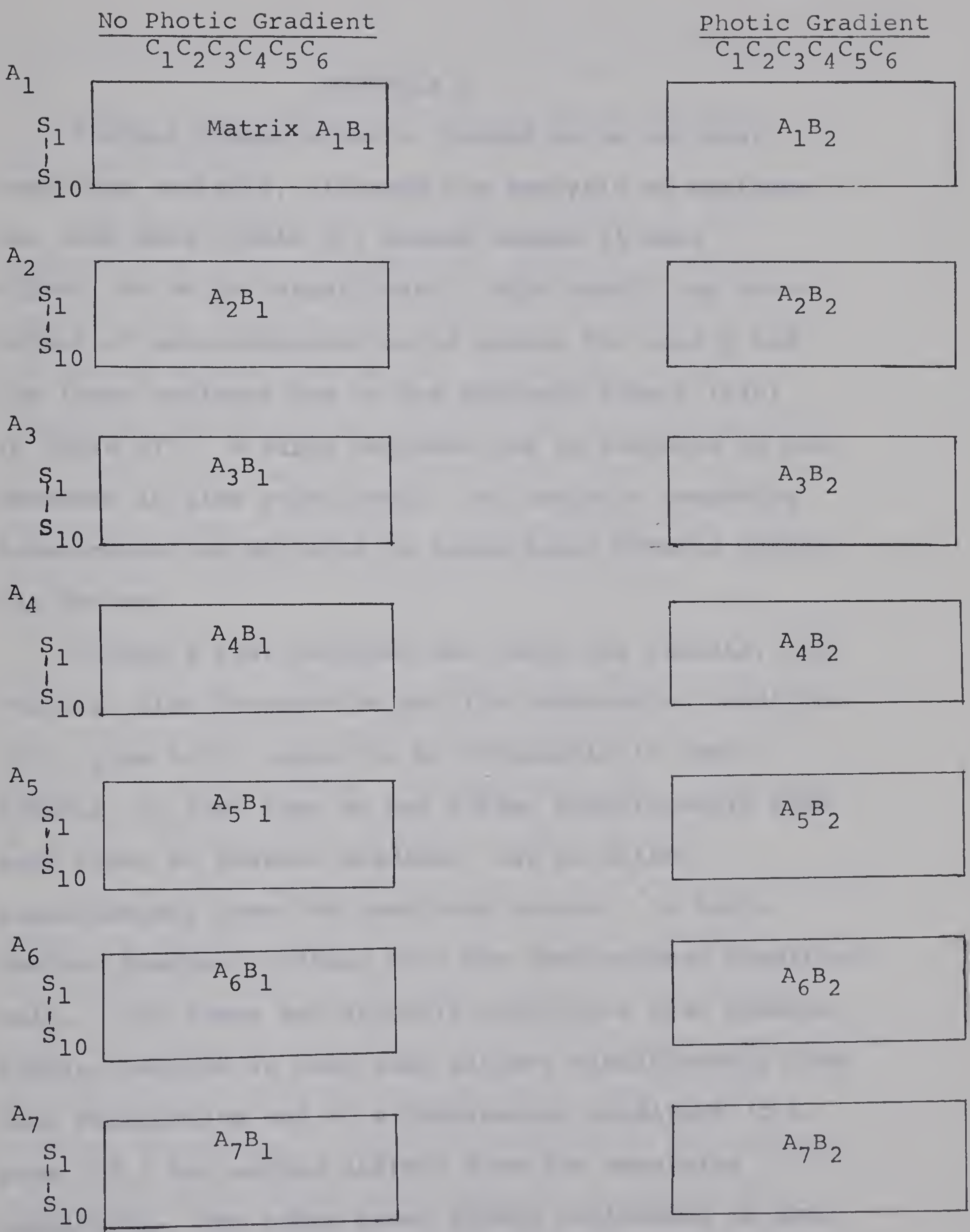

Table X: Inset
Size data (in minutes of visual angle) as arranged in matrices for analysis of variance by APL. The fourteen matrices represent seven levels of A (scenes) by two levels of gradient (Photic Gradient-No Photic Gradient). Each matrix represents data for ten Ss over six elevations. Inset shows the positions of the

APPENDIX 4

Terrain characteristic proved to be the most important variable, although the analysis of variance for size data (Table II) showed scenes (A main effect) to be not significant. This result may be an effect of non-randomization of scenes for each S and the large variance due to the Subjects effect (S(A) in Table II). A large variance due to Subjects is not uncommon in size experiments. An analysis comparing foregrounds was employed to investigate effects within the factor.

Duncan's test produced few clear-cut results, but overall, Line Perspective and it's Combination condition (C.S. plus L.P.) appear to be comparable in their effects, in that they do not differ significantly from each other or Texture Gradient, but do differ significantly from the remaining scenes. In fact, Texture Gradient differs from the Unstructured Condition only. City Scene and Windmill conditions also produce similar results in that each differs significantly from Line Perspective and it's Combination condition (C.S. plus L.P.) but neither differs from the remaining conditions. The other gross effect noticeable is that the Unstructured Condition and Windmill condition appear to produce comparable data - they do not differ

significantly from each other, and comparisons with all other scenes yields the same results for both, with one exception.

Further analysis of the scenes compared each foreground with the Unstructured Condition. This comparison is particularly important to determine the effects of scene independent of elevation. This comparison for total data showed that the Combination (C.S. plus L.P.) evoked significantly more illusory size than absence of scene. The comparison for Line Perspective, however, approached significance. A comparison of scenes with the absence of scene for data from the photic condition produced the added result that Texture Gradient approached significance in its ability to evoke greater illusory size than the absence of scene (under photic gradient condition only).

The classic comparison "Size of Horizon Moon"/"Size of Zenith Moon" (see page 11) was also influenced by the particular foreground under which it was tested. This size index is greatest in the Combination conditions, and relatively large in the City Scene and Texture Gradient conditions. The Line Perspective and Windmill conditions showed only an approximate twenty percent increase in size from zenith to horizon. Changes in size under the Unstructured Condition were minimal.

It would then appear, from the evidence cited, that the peculiar terrain under which the moon is viewed affects both absolute and relative illusory size.

APPENDIX 5

A Friedman two-way analysis of variance by ranks[1] tested the role of each component in the combinations. The analysis was applied over elevations rather than Ss. Results are shown in Table XI.

Results indicate that in the Combination (C.S. plus T.Gr.), Texture Gradient was significantly different from its combination condition, while City Scene was not. Of the components of the Combination (C.S. plus L.P.), City Scene proved significantly different while Line Perspective did not. In fact, by this analysis, Line Perspective is a true alternative for its combination condition i.e. Line Perspective is highly dominant in the combination.

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[1]from Ferguson, Statistical Analysis in Psychology and Education (1959), p. 272-274.

Table XI

source	χ_r^2	df	p	interpretation
C.S. vs. C.S. plus T.Gr.	2.7	1	> .10	a · ab = ?
T.Gr. vs. T.Gr. plus C.S.	6.0	1	< .02	b · ba = S
C.S. vs. C.S. plus L.P.	6.0	1	< .02	a · ac = S
L.P. vs. L.P. plus C.S.	0.0	1	=1.00	c · ca = N.S.

In the interpretation: "a" represents C.S.
"b" represents T.Gr.
"c" represents L.P.

S. represents significance
N.S. represents non-significance

Table XI: Friedman analysis comparing each component with its combination condition. Interpretation shows a schematic representation of the factors and evaluates their role in the combination.

GLOSSARY

APL - A Programming Language - a machine-executable version of the Iverson language[1].

illusory size - There are two aspects of illusory size:

1. relative illusory size is defined as the traditional comparison "Size of Horizon Moon"/"Size of Zenith Moon", variations of which were used by Boring (1939), (1943), Kaufman and Rock (1962), etc.

2. absolute illusory size is defined as deviation of judged size from veridical stimulus size.

radiant light - light which is propagated outward from an incandescent substance (sun, fire) with enormous velocity[2], or the energy (photus) radiating from a point such as an atom[3].

luminous light - psychophysical in nature, in contrast to radiant light, which is defined in physical terms.

sensible horizon - a plane passing through the eye of the spectator at right angles to the vertical at a given place[4].

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[1]An Introduction to APL/360, p. 1

[2]The Senses Considered as Perceptual Systems, p. 12

[3]communication, J.J. Gibson, U. of A., Edmonton, 6/68

[4]Webster's New Collegiate Dictionary, Thomas Allen Ltd., Toronto, 1961, p. 398.